

METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER)

Readers are invited to submit articles for publication in the editorial pages; photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 21, Albion Street, Manchester, 1.

PRINCIPAL CONTENTS IN THIS ISSUE:

	Page		Page
The Future of British Steel	97-98	The Blast Furnace Burden. By Theodore Powell	121-125
Joint Iron Council	98	<i>The blast furnace determines the character and quality of pig iron produced and has a direct influence on the cost of steel. The operation of this furnace is discussed in relation to steelworks' requirements, pre-war and wartime burdens, the ideal burden, and particular attention is directed to coke. British blast furnace practice is discussed.</i>	
The Passivation of Zinc Using Dichromate Base Solutions, with Special Reference to Electro-zinc Deposits. By E. E. Halls	99-104	High Tensile Steel for Castings. By W. West, C. C. Hodgson and H. O. Waring	126-132
<i>The passivation and chromatising treatments of zinc surfaces have been developed to give the maximum service with the minimum of material. These treatments have reached a stage of commercial stability and are worthy of careful consideration. The subject is discussed and experimental results given.</i>		<i>Various aspects of steelmaking and foundry practice, investigated by the authors during the past five years are co-ordinated. The type of steels were of the low and medium alloy varieties capable of giving ultimate tensile strengths from 35 to 65 tons/sq. in. on sections up to 4 in. or as high as 75 tons/sq. in. on smaller sections.</i>	
A Routine Method for the Analysis of Nickel Bronze. By W. T. Elwell, F.R.I.C., and J. McPheat	105-107	Segregation of Metals and Alloys	133-134
<i>Nickel-bronze alloys contain copper, tin and lead in major proportions and may contain small amounts of iron, manganese and silicon. They contain from 10 to 80% of nickel. A method is described for the complete analysis of these alloys.</i>		<i>Some aspects on segregation are considered, including fundamental principles involved in segregation of alloy castings and factors underlying segregation in steel ingots.</i>	
The "Javelle" System of Heat Resisting Units for Furnace Damper and Hearth Construction	107-108	Investigation of Metal Pouring by Ciné Photography	135-136
<i>The furnace damper controls the flow of gases and regulates rate of heat admission, it is therefore an important item in obtaining the utmost efficiency from the fuel.</i>		<i>A new technique developed to enable the examination of the flow of metal as it enters a mould.</i>	
The Position of Metallurgists in Russia	108	Application of Micro Combustion Technique to Metallurgical Analysis. Part I. By G. Ingram	137-140
The Iron and Steel Institutes	109-114	<i>Problems associated with the application of micro-combustion technique to the determination of carbon in steels are discussed.</i>	
<i>Seventy-sixth Annual General Meeting.</i>		Metallurgical Digests	141-146
The British Iron and Steel Industry	115-120		
<i>Difficulties, encountered in producing iron and steel during the war, are discussed. Attention is directed to achievements of the industry recently revealed and some contributions to the war effort by representative iron and steel firms are briefly outlined. It is noteworthy that, despite difficulties, production increased during the period.</i>			

Subscription Rates throughout the World - - 24/- per annum, Post free

Published monthly by THE KENNEDY PRESS, LIMITED.

REGISTERED OFFICE: 31, King Street West, Manchester, 3.
Telephone: BLA 7086-7. Telegrams: "Kenpred," Manchester.

LONDON OFFICE: Bedford Street, W.C. 2.
Telephone: Temple Bar 2029.

ACTARC

Bronze electrodes

● FOR WELDING TIN BRONZES AND GUN METAL

● FOR WELDING BRASSES, ALUMINIUM BRONZES,
COPPER, CAST IRON AND STEEL

● FOR WELDING COMPLEX ALUMINIUM BRONZES,
MANGANESE BRONZE, COPPER AND STEEL

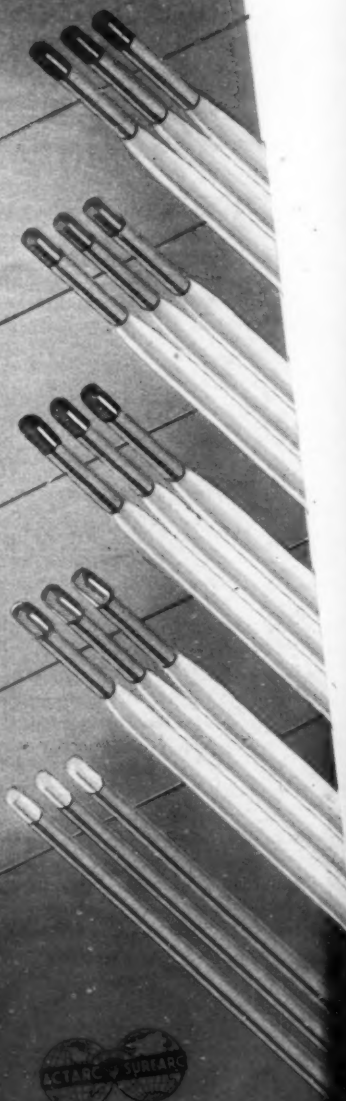
● FOR WELDING EVERDUR

● FILLER ROD FOR CARBON ARC WELDING
OF COPPER

SEND ENQUIRIES TO THE RESEARCH LABORATORIES
ARC MANUFACTURING CO., LTD.

60B, CRAVEN PARK ROAD, N.W.10.
REG. OFFICE AND WORKS: GOLDHAWK ROAD, W.12

TELEPHONE: ELGAR 4781
TELEPHONE: SHE 1131



METALLURGIA

THE BRITISH JOURNAL OF METALS.

INCORPORATING "THE METALLURGICAL ENGINEER."

JULY, 1945

VOL. XXXII. No. 189

The Future of British Steel

ELSEWHERE in this issue has been given a brief outline of some of the difficulties encountered by the British iron and steel industry as a result of changed conditions caused by war. Despite these difficulties, however, production increased from about 10 million tons a year to nearly 14 million tons and the industry never failed to meet every demand the Services made upon it. Apart from the production of carbon steels of various grades, special qualities of alloy steels were necessary for aeroplane engines and other uses, special armour plate had to be produced, special forgings for tanks and other transport equipment, and these, together with many other operations and multitudinous applications for carbon, alloy and special steels had bestowed upon them much highly scientific research. The availability of supplies of raw materials, the majority of which were imported before the war, necessitated considerable changes in the composition of alloy steels and much research was necessary to set up standards which would utilise the minimum of precious alloying elements and yet possess adequate strength for specific applications.

In war-time the actual demands on steel, whether of carbon or special alloy quality, are usually higher than in normal times—the conditions are more severe—yet the service obtained from some so-called "substitutes" has been a source of surprise to many engineers who are in a position to make comparisons with steels formerly used. Research has done much to overcome difficulties both in the manufacture and use of these substitute steels and to overcome prejudices. Indeed, so much progress has been made, in the relatively short time they have been applied, that many substitute steels will receive permanent recognition when peace-time standards are determined. And it is extremely doubtful whether the industry will return to the wider range of specifications for which it catered in pre-war days. It is probably true, as has been suggested, that the range of qualities will increase, but every effort should be made to prevent a return to the number of steel compositions manufactured in this country before the war. It is noteworthy that with the more general use of substitute carbon and carbon-manganese steels for normal alloy steels, greater attention has been given to their heat-treatment to provide the properties most desired, and this is all to the good.

Before the war too much attention was focused on the composition of a steel for a particular part, rather than upon its ultimate physical properties. The war has checked this tendency, but the change of view is one for the engineer or designer, since the steel producer is not generally aware of the specific application of the component for which the steel is to be used.

With the gradual return to more normal conditions the progress achieved for war purposes will provide the foundation for peace-time production. It should be remembered, however, that the technical and scientific achievements have not been limited to iron and steel. In other metal producing fields the war-time achievements have not been less spectacular. In all these fields developments have been made at a pace without precedent, and as critical shortages of various metals are not now so acute, competition between makers of these different materials will be resumed, especially in the range of applications over which the utilisation of different materials now overlap. Although many metals are a natural solution for the majority of uses to which they are put, no definite demarcation exists in the use of different materials.

It is probable that aluminium will make some progress at the expense of steel, but the percentage will be small, indeed, the steel industry is justified in believing that the immediate future will create a demand for all the steel it can make. At present, changes in industry to peace-time production are proceeding very slowly and the demand for steel does not absorb the capacity of plants, but gradually more settled conditions, and a return to the production of goods and equipment so long needed, will make increasing demands for steel. While the immediate future of the industry, however, is important, a long-term policy is necessary upon which a sound future can be built.

On acquiring protection in 1934, a condition was that the iron and steel industry should put its house in order and it is noteworthy that from that time until the beginning of the war production had nearly doubled. During that time considerable reorganisation had been effected and many plants modernised and brought to a state of efficiency comparable with that in any other countries. Some works were in process of reorganisation, while others had prepared schemes and were about to begin when war was declared. This upheaval brought to a halt the many schemes and little has been done to modernise plants since the war began. But the position of the country would have been more critical, especially during the early part of the war, if the steel industry had not doubled its output.

Now, modernisation must proceed and effect given to the promise of 1934. Nearly six years of war, in which steel plants have been worked to their utmost, with the minimum of maintenance and renewals, has left the industry in a relatively weak condition. New plants will be essential and greater emphasis should be placed on efficiency to reduce cost than upon the commercial organisation and selling of the products.

The future will hold many problems for the iron and steel industry and there can be no doubt that the co-operative plan adopted by the British Iron and Steel

Federation will do much to solve them through the services of highly qualified technicians available.

Stimulated by war, the need for goods and services, both at home and abroad, is considerable. At home, in particular, the demand for steel will approach new high levels for several years. In markets abroad, however, especially those not directly in the war, considerable development has been inevitable and it will go on when the world war is over. Signs of this development are not lacking in the Dominions, in Sweden, in the Argentine and in South America generally, which it would be foolish to ignore. Countries that have been consuming countries in the past are becoming industrialised and this will undoubtedly entail changes in the form of the exports which Britain has sent in the past, but, raising

the standards of living, and the demands which industrialisation brings with it, cannot in the long run do other than redound to the advantage of this country in which the steel industry will participate.

It is generally recognised that, in times of peace, those responsible for directing industry pit their organising, productive and commercial ability against contemporary competition from wherever it may come and, according to the degree of enterprise and leadership displayed in each unit of industry, efficiency, in the end, outstrips inefficiency. We have seen what leadership can do in directing war; let us profit from the examples and use stimulating imagination, foresight, genius, and vigorous action in overcoming the steel industry's problems, so that serviceable steel at a competitive price will be available, the future for steel will then be assured.

Joint Iron Council

MR. ARTHUR R. KNOWLES, O.B.E., has been appointed Director of the Joint Iron Council, a national body formed recently by the producers of foundry pig iron and the Council of Iron Foundry Associations.

The purpose of the Council is to represent the industry in all matters of common interest to all its sections.

Mr. Knowles has been Secretary of the Sheffield Chamber of Commerce since February, 1935. Born at Dursley, Gloucestershire in 1899, he served during the 1914-1918 war in the Artists' Rifles and the Royal Flying Corps. In 1919, he joined a British firm in China. In 1925, Mr. Knowles returned to this country. In 1927, he took up an appointment as Assistant Secretary of the Manchester Chamber of Commerce, in which position he remained until 1934, when he accepted an invitation to become Secretary of the Russo-British Chamber of Commerce, in London.

The Joint Iron Council has two members only—the first an association representing producers of pig iron (other than iron for steel-making purposes). This association is called the Council of Iron Producers. The second is the Council of Ironfoundry Associations, which was founded in 1941 as a confederation of the numerous ironfounders' trade associations throughout the country, to act as a united body to represent the whole industry in matters of common interest. The Council of Iron Producers is a more recently constituted organisation, which represents all the makers of iron used in foundries, including cylinder and refined iron.

The national and fundamental character of the industry represented by these two bodies cannot be too highly stressed, particularly in view of the post-war programme of the building and engineering industries at home and for export. Furthermore, the technical advances made in the industry during the past five years have been outstanding and compare very favourably with those made during the last war and one of the chief objects of the new organisation is to ensure that full advantage of these improvements is taken all through the industry, which comprises some 1,800 different establishments distributed all through the British Isles.

It was made quite clear during the course of the discussions which led to the formation of the Joint Iron Council that the organisation has not been set up in any spirit of antagonism to the British Iron and Steel Federation, which organisation is primarily concerned

with the interests of the producers and consumers of steel. As is known, the British Iron and Steel Federation recently decided to reorganise on a somewhat similar basis—i.e., membership being confined to associations, and it is anticipated that there will be close co-operation between the two bodies whenever necessary, and in order to avoid any overlapping.

The first president of the Joint Iron Council is Mr. H. H. Berresford, managing director of the Staveley Coal and Iron Company Limited, who is the present chairman of the Council of Iron Producers.

The vice-president of the Joint Iron Council is Mr. FitzHerbert Wright, who has been largely responsible for the formation and organisation of the Council of Ironfoundry Associations, and is its present chairman.

The general management and control of the Joint Iron Council is vested in a council of 20 representatives appointed by the Council of Iron Producers and by the Council of Ironfoundry Associations equally

Ferro-Alloys

In the production of steels and irons, both plain carbon and alloy, the necessary alloying and cleansing elements are added to the base metal principally in the form of ferro-alloys, which are mixtures or compounds of the cleansing and alloying elements with iron. In order to assist the user to select the ferro-alloy or alloying metal best suited to his individual needs a booklet has been prepared, containing much useful information. It covers the many chromium, manganese, silicon, calcium and zirconium alloys available, together with reasons for the use of each in open-hearth, converter, and foundry practice. A section devoted to briquetted alloys tells how chromium, manganese and silicon additions can be made for the improvement of cast iron. Further sections discuss the use of manganese and silicon metals in non-ferrous metal production.

This booklet of 36 pages is the first to be published of a series of technical publications being prepared by St. Lawrence Alloys & Metals Ltd. As with those in preparation, this booklet is available in English, Spanish, Portuguese and French editions. In making applications for copies on business notepaper, interested readers are requested to specify the language most useful to them.

Application should be made to St. Lawrence Alloys and Metals Ltd., 340, University Avenue, Toronto, Ontario, Canada.

The Passivation of Zinc using Dichromate Base Solutions, with special reference to Electro-Zinc Deposits

By E. E. Halls

The passivation and chromatising treatments of zinc surfaces have been developed to increase the service obtainable from zinc surfaces and thereby provides the maximum efficiency with the minimum of raw material. These treatments have reached a stage of commercial stability and are worthy of careful consideration with a view to their increased application. The author discusses this subject and gives the results of experimental investigations.

ZINC has been recognised for many years as the coating material for first consideration in the rust-prevention of iron and steel. It is used extensively for this purpose, as a hot dip coating commonly referred to as "galvanising," as an electroplate deposit applied by cathodic deposition from a suitable aqueous electrolyte, and as a metal sprayed coating. It functions in its role as rust preventer by itself corroding, generally to white growths of zinc compounds. Obviously, sufficient zinc must be provided in the thickness of the coating to serve the estimated service life in any predetermined set of conditions. Any treatment that suppresses this deterioration and thereby imparts a longer life to the same thickness, or the same life to a thinner coating, warrants consideration if only on the basis of economy. Efficiency is, however, also involved, apart from appearance, as well as the factors of maximum speed of production, maximum efficiency and minimum of raw material, all factors emphasised by the war situation, and equally vital from the national resources point of view in the post-war period. The treatments for zinc described as "passivating" and "chromatising," among other terms, fall in this category. They have now reached a stage of commercial stability and assuredness that they demand serious attention by all executives and technicians concerned with zinc and zinc coatings in applied engineering.

Treatments for zinc surfaces including zinc castings, galvanised iron and zinc plated components, have been used for a long period. Most of them have been developed and resorted to with a view to rendering the zinc surfaces relatively inert so that, when paint, enamel, varnish, etc., is applied, the reactivity of the zinc has been suppressed and it does not gradually react over a period of time with the resinous or fatty acidic ingredients in the coating. In other words, it is expected that organic coatings on zinc are unsuitable and some treatment has to be applied in order to render them serviceable for extended periods.

Of the numerous processes that have been evolved, and most of them consist in a simple dip treatment of the work in a carefully balanced chemical solution, a few in recent years have been established as very sound. This particularly applies to their application to zinc die-castings, but, to a lesser degree to electro-zinc platings. There are several reasons for the short-comings of the treatments on zinc plate, for example, the zinc coating is often thin, usually it is porous or very porous, and its distribution over the surface is very uneven.

It will be noted, therefore, that the treatments have been concerned with stabilising another coat which is to be applied.

In more recent years, however, attention has been given to developing these treatments so that the zinc surfaces are less prone to deterioration under normal exposure conditions, including moist atmospheric conditions. Zinc, under such circumstances, gradually stains and becomes white, due to the formation of zinc corrosion compounds, and this is more noticeable with porous coatings such as protective films on steel, than it is with solid castings which have their die-cast surfaces undisturbed.

Under damp conditions such as experienced in the tropics, deterioration of zinc coatings may be quite rapid and the appearance becomes objectionable, but, moreover, the white deposits powder off and, if moving elements or electrical contacts are concerned, they may cause loss of efficiency or failure of equipments. Again, the rapid deterioration of zinc coatings means that the zinc is becoming consumed and, therefore, the protective life of the film becomes exhausted and thicker coatings become essential. This is more costly, and when dimensional limits are very close, thicker coatings may be impracticable.

A number of treatments, usually based on di-chromate solutions, have been evolved whereby the zinc surfaces are rendered passive under ordinary conditions of exposure and even under many very severe influences. Treatments in these solutions have an effect on the zinc similar to the influences of the flash chromium plate on nickel coatings, thus rendering them virtually immune from attack, due to a phenomenon of "passivation."

The simplest of these solutions are water solutions of sodium di-chromate acidified with sulphuric acid. The di-chromate alone does not serve the purpose and one explanation is that slight dissolution of the zinc in the sulphuric acid occurs, followed by precipitation of zinc chromate. This reaction would take place to a minute extent giving an exceptionally thin film tenaciously absorbed on to the surface of the zinc. This zinc chromate film would serve as an effective inhibitor of corrosion just as it does when present in the primer coat used extensively as finishing magnesium and its alloys.

Modern theories tend to the view that chromium chromate is formed on the surface of the work and research indicates that trivalent chromium is present in the film as well as hexavalent chromium. Treatments

in such solutions tend to give a yellow to yellowish-brown colouration which may be quite irregular, dependent upon the nature of the surface.

Work done in recent years with the object of obtaining the maximum benefit from such treatments and maintaining uniformity under production conditions has shown that these simple solutions require the inclusion of additional agents in order to keep their balance correct. A number of proprietary processes are offered which have virtually the dichromate sulphuric acid base, but which contain other ingredients such as inhibitors to reduce the attack on the zinc to a minimum, and oxidising agents in order to keep the hexavalent chromium to the optimum level.

Obviously the appearance of the film produced from such treatments depends on the nature of the surfaces to which applied, in particular, upon the uniformity of the zinc coating, its porosity or density. Thus probably the best results are obtained on zinc produced from the rapid bright zinc plating processes and less satisfactorily, at least from an appearance point of view, results on the very irregular porous coatings produced by ordinary plating processes on work of very irregular shape. The proprietary processes will yield iridescent types of film, the most efficient having a greenish hue.

All these processes entail the immersion of the clean wet work in the treatment solution at ordinary temperatures for a matter of a few seconds, the average time being 10 to 15 seconds. Work from plating vats, if properly washed, can pass, still wet from the washing operations, but if for some particular reason it has been allowed to dry out, it should be re-wetted in cold and hot water.

The dry metal-sprayed coatings of zinc need to be wetted and if they have been handled or allowed to lie about for some time they should be degreased, for example, in trichlorethylene vapour, and then passed through cold and hot water in order to wet completely the surfaces and eliminate any retained air bubbles. After treatment it is merely a question of thorough water washing to remove all chemicals, and drying off. The latter is best achieved in warm air and one of the usual hot-air circulation ovens is most appropriate. A temperature of the order of 60° C. is all that is necessary and excessive temperature should be avoided.

The relative merits of some of these processes can be exemplified by test results on treated specimens. Attached tables give such data for a range of types. The base material used for the specimens was mild steel sheet and two types of zinc plating were covered, namely zinc plating from a cyanide electrolyte and zinc plating from a sulphate solution. In the latter case, of course, the deposition had to be preceded by a flash of zinc from cyanide solution in order to obtain coverage. The thickness of plating nominally aimed at in both cases was 0.0003 in. minimum, or expressed in terms of weight, a minimum of 500 m/gram. per square decimetre.

Corrosion tests were applied to specimens in the untreated condition and treated by various passivation methods. These included the straight-forward sodium dichromate sulphuric acid solution, a simple dilute chromic acid solution and the modified di-chromate solutions that are marketed by several firms. Incidentally the straight chromic acid solution was included as a

matter of interest because this is used as a final dip after plating, particularly when the zinc cyanide electrolyte is used, in order to destroy alkaline chemicals retained in pores or seams.

The test conditions to which samples were subjected included salt spray at ordinary temperatures, severe humidity of 100% at 60° C., and more mild humid

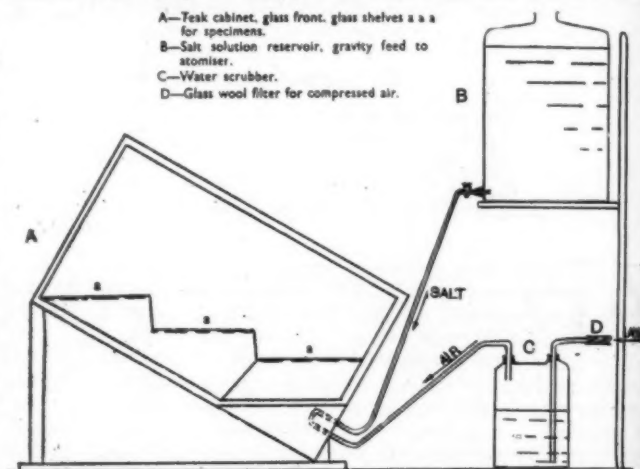


Fig. 1.—Section of salt spray apparatus.

conditions.

In the salt spray test, the specimens were subjected to the mist produced by atomising 20% salt solution with compressed air. The compressed air was cleaned by passing through a filter of glass-wool and maintained moist by passing through water. The spray was operated during the eight-hour day period and the specimens left in the mist-laden cabinet overnight. Each day they were washed in running mains water and dried on a soft cloth for examination. A sketch of the apparatus is shown in Fig. 1.

The severe humidity test virtually comprised that to the wireless telegraphy board Spec. K.110. All specimens were first exposed to a temperature of 71° C. for 6 hours and allowed to cool off for the rest of the day in the oven. They were then subjected to two successive cycles of 95 to 100% humidity at a temperature of 60° C., this being maintained for six hours and the specimens left to cool in the cabinet for the remainder of the day. The apparatus is shown diagrammatically in Fig. 2.

More mild humid conditions were obtained in a special cabinet in which day conditions for 8 hours were maintained with a temperature of 55° to 60° C. and a humidity of 60 to 70%. During the night the cabinet was allowed to cool off and humidity rose to 95 to 100% with water condensation upon the specimens. The humid conditions were obtained by means of a tray of water on the base of the cabinet. Temperature was controlled from electric heaters in the cabinet with resistance control externally. A fan gave reasonable uniformity of conditions. Diagrammatically the apparatus is shown in Fig. 3.

The conditions employed for the sodium dichromate sulphuric acid treatment comprised 15 seconds immersion at ordinary temperature of about 70° F. in the following solution :—

Sodium dichromate, 200 lb.
Sulphuric acid, 6 pts.
Water, 100 gals.

The chromic acid solution used the same conditions of temperature and time and the solution concentration was 25 lb. of chromic acid in 100 gals. of water. The proprietary solutions were operated at room temperature and in method A immersion times of 10 to 15 secs. ; and method B of 3 to 5 secs. were employed.

generally speaking, rather superior to those from the straight sulphuric dichromate method. The simple chromic acid treatment was beneficial, but the value of it was negligible in comparison with that of the other processes. There is, therefore, no doubt that the treatments do passivate the zinc surfaces and prevent corrosion of the zinc itself under moist conditions and under even more rigorously corroding conditions to a very material extent.

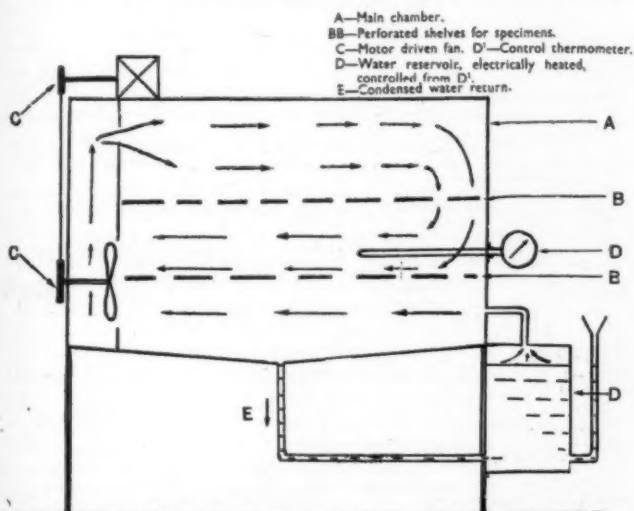


Fig. 2.—Diagrammatic section of test apparatus for 100% humidity at 60° C.

Results given in Tables I and II are mainly self explanatory and only call for comments. In general, it can be stated that the treatments were equally effective on zinc from cyanide and sulphate electrolytes.

Results from the proprietary treatments were,

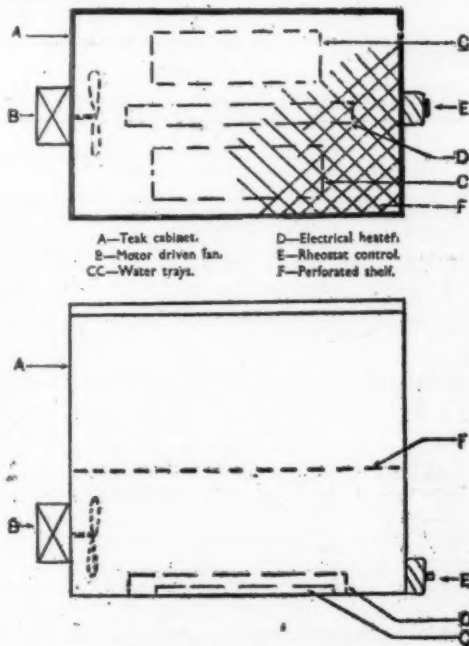


Fig. 3.—Showing diagrammatically mild cyclic humidity test cabinet.

TABLE I.

Results of Salt Spray Tests upon Steel Specimens Zinc Plated from Cyanide Electrolyte, comparison with and without passivated treatment.

Period of Salt Spray Test in days.	Behaviour under Salt Spray Conditions of Zinc Plated Steel Specimens from Cyanide Electrolyte.		
	(1) No Passivation.	(2) Treated in Sodium Dichromate/Sulphuric Acid Solution.	(3) Treated in Chromic Acid Solution.
1	Appearance was generally mottled, dirty grey in colour.	Virtually unaffected.	Isolated dirty grey mottled patches.
14	White incrustations around all edges.	A few pin-point black spots and one or two larger spots.	White zinc compounds formed along edges.
28	Marked general whitening due to formation of zinc compounds, and a number of tiny rust spots.	General whitening but very slight in intensity, most marked at edges. Very few small rust spots. Performance outstandingly better than sample (1) with no passivation—or sample (3).	General whitening, most marked at edges, and a few rust spots at edges. Condition in general little superior to sample (1).

TABLE II.

Results of Salt Spray Tests upon Steel Specimens Zinc Plated from Sulphate Electrolyte, comparison with and without passivation treatment.

Period of Salt Spray Test in days.	Behaviour under Salt Spray Conditions of Zinc Plated Steel Specimens from Sulphate Electrolyte.		
	(1) No Passivation.	(2) Treated in Sodium Dichromate/Sulphuric Acid Solution.	(3) Treated in Chromic Acid Solution.
1	Generally revealed a grey mottled appearance.	Virtually unaffected.	A number of grey mottled patches developed.
3	—	—	Mottled areas increased.
14	Growth of white zinc compounds around edges.	Only a few blackish pin-points developed.	A number of dark pin-point spots developed, also white corrosion at edges.
28	Increase in whitening at edges, and slight general whitening, but no rusting.	Some whitening at edges, no further deterioration from the black pin-point spots. General condition very good, main surfaces practically unaffected. Markedly better than sample (1) of zinc plate with no passivation, and than sample (3).	Increased attack at edges, no rusting and general condition little different from that of sample 1.

TABLE III.

Results of 100% Humidity Test at 60° C. on Steel Specimens Zinc Plated from Cyanide Electrolyte, comparison with and without passivation treatment.

Period of Test.	Behaviour under Test.		
	(1) No passivation.	(2) Treated in Sodium Dichromate Sulphuric Acid Solution.	(3) Treated in Chromic Acid Solution.
First day.	Fairly heavy white corrosion products over all surfaces.	Only one small area of whitening, otherwise unaffected.	Slight general white corrosion over most of surface.
Second day.	Increased attack, heavy white corrosion general.	Local area of white corrosion heavier but general surfaces still unaffected. Markedly superior to sample (1) of zinc without passivation.	Increased attack, fairly heavy general white corrosion, nearly as bad as sample (1) of zinc without passivation.

TABLE IV.

Results of 100% Humidity Test at 60° C. on Steel Specimens, Zinc Plated from Sulphate Electrolyte, comparison with and without passivation.

Period of Test.	Behaviour under Test.		
	(1) No passivation.	(2) Treated with Sodium Dichromate/Sulphuric Acid Solution.	(3) Treated in Chromic Acid Solution.
First Day.	General corrosion to fairly heavy white deposit of zinc compounds.	One localised area of attack to slight white deposit, general surfaces unaffected.	Slight general white corrosion over most of surface.
Second Day.	Attack progressive, heavy white corrosion general over all surfaces.	Increased attack at localised area but general surfaces still showing no deterioration. Markedly superior to sample (1) of zinc without passivation.	General deterioration to fairly heavy white corrosion deposits, condition closely similar to sample (1) of zinc without passivation.

TABLE V.

Result of 100% Humidity Test at 60° C. on Steel Specimens Zinc Plated from Cyanide Electrolyte, comparison with and without passivation in modified Dichromate/Sulphuric Acid Solutions.

Period of Test.	Behaviour under Test.		
	(1) No passivation	(2) Modified Treatment A.	(3) Modified Treatment B.
First Day.	Fairly heavy white corrosion products over all surfaces.	A few small isolated patches of white corrosion but general surface unaffected.	One or two local patches of white corrosion, but in general no deterioration.
Second Day.	Increased attack, heavy white corrosion general.	Increase in intensity of attack on local areas but general surfaces still unaffected.	Corrosion patches heavier but not extended, and in general no real deterioration.

TABLE VI.

Results of 100% Humidity Test at 60° C. on Steel Specimens, Zinc Plated from Sulphate Electrolyte, comparison with and without passivation in modified Dichromate/Sulphuric Acid Solutions.

Period of Test.	Behaviour under Test.		
	(1) No passivation.	(2) Modified Treatment A.	(3) Modified Treatment B.
First Day.	General corrosion to fairly heavy white deposit of zinc compounds.	A very light film of white corrosion developed.	A few small white corrosion spots formed, but general surfaces were unaffected.
Second Day.	Progressive attack, heavy white corrosion deposits over all surfaces.	No further deterioration, markedly superior to sample (1) of zinc plate without passivation.	No further deterioration, and condition very good, markedly superior to sample (1) of zinc plate without passivation.

TABLE VIII.

Influence of Passivation of zinc plate upon subsequent enamelling. Shown by mild cyclic humidity test (warm and dry, cold and moist) on cellulose enamelled specimens. Finish consisting of two spray coats of white cellulose enamel. Total period of test, 20 days.

Sample No.	Zinc Plate Electrolyte.	Passivation Process.	Ageing of cellulose enamel finish shown by:—			
			Adhesion on Bend Test		Adhesion on Scratch Test.	
			Initial.	After 20 days' test.	Initial.	After 20 days' test.
1	Cyanide	None.	Very good to excellent.	Rather poor to very poor.	Very good.	Rather poor to very poor.
2	"	Dichromate/Sulphuric Acid.	" " " "	" " " "	" " "	Very poor.
3	"	Chromic Acid.	" "	" "	" "	Rather poor.
4	"	Modified Dichromate A.	" "	Very poor.	Very good to excellent.	" "
5	"	" " B.	" "	" "	Very poor.	Very poor.
6	Sulphate.	None.	Variable, very good to very poor.	Rather poor to very poor.	Variable, very good to rather poor.	Rather poor to very poor.
7	"	Dichromate/Sulphuric Acid.	Very good.	Very poor.	Very good to excellent.	Rather poor to very poor.
8	"	Chromic Acid.	Very good to excellent.	Rather poor to very poor.	Very good.	Rather poor.
9	"	Modified Dichromate A.	Very good to excellent.	Very poor.	Very good.	Rather poor.
10	"	" " B.	Very good.	Very poor.	Rather poor to very poor.	Rather poor to very poor.

Thus, from Table I, it is seen that, under the very vigorously corroding conditions of salt spray, the sulphuric and the sodium dichromate treatment gives real protection to zinc plated from a cyanide electrolyte. Table II reveals the same remarkable passivity afforded to zinc deposited from an acid sulphate electrolyte. Again, in Table III, is demonstrated the valuable degree of resistance to whitening conferred upon zinc coatings from cyanide solutions by this same treatment, the test conditions being the vigorous ones combining warmth and wetness. Table IV depicts the same results for the sulphate zinc deposits. Tables V and VI cover these warm-wet conditions for cyanide and sulphate types of platings passivated in the proprietary solutions of modified sulphuric acid/sodium dichromate base. It will be noted that passivation approaching complete immunity from attack is achieved. Finally, under the less arduous conditions of the mild cyclic humidity test, complete protection is secured by all of the sulphuric acid/sodium dichromate types of process, this being shown by the brief summary in Table VII.

Regarding the influences of the passivation on enamel coatings, this is dealt with in Tables VIII to XI. From the wide range of tests carried out in a strictly comparative manner, the passivation certainly causes no harm to the enamel finish, and there is a tendency for a slight improvement in the serviceability of the enamel coating, particularly in the case of stoved enamel. Cellulose enamel is covered by the data in Table VIII, and stoved synthetic enamel by those in Table IX. The enamels themselves were normal industrial qualities, and their salient characteristics are presented in Table X.

On the other hand, from these tests, it cannot be claimed that the treatments are warranted for the stabilisation of the enamel coating alone. In this respect they are entirely different from the phosphate treatments used for iron and steel such as well-known bonderising processes, in which the phosphatisation produces true adhesion, but also gives added resistance to enamel film to eliminate or minimise any ageing effects.

Regarding the tests used for adhesion of the enamel coatings, these were carried out in the following manner:

In the bend test, the specimens were slowly folded through an angle of 180° around a diameter of $\frac{1}{4}$ in., the

TABLE VII.

Results of Mild Cyclic humidity test (warm and dry, cool and moist) on Zinc plated specimens. Comparison with and without passivation treatment. Total exposure period, 60 days; zinc plating from cyanide and sulphate electrolytes.

Sample No.	Treatment after Zinc Plating.	Condition after 60 days test period.
1	No passivation.	Discoloured over all surfaces, generally to whitish and greyish mottle or stain.
2	Treated in sodium dichromate/sulphuric acid solution.	Unaffected, no deterioration.
3	Treated in chromic acid solution.	General discolouration but not so intense as with sample (1) of zinc plate with no passivation.
4	Modified dichromate treatment A.	Unaffected, no deterioration.
5	Modified dichromate treatment B.	Unaffected, no deterioration.

rate of bending being such that the time taken was about three seconds. The enamel finished side of the panel, of course, was on the outside of the bend.

In the scratch test, a hardened steel rod tapered off to a cone with a flattened end, the latter being $\frac{1}{16}$ in. diameter and the conical angle being about 15°, was employed. This was drawn firmly and vertically across the enamel surface, the pressure applied being arranged so that the enamel film was just cut through. Assessment was usually made by making two such cuts one across the other at an acute angle. Details of the method of assessment are given concisely in Table X.

It is evident that the thickness of the zinc coating and its physical condition with respect to porosity must have appreciable bearing on the benefit of the passivation treatment. The zinc plating process should always be selected to give maximum uniformity of coverage of the work with the zinc, and the thickness of deposit average should never be less than 0.0003 in. and the thinnest area not less than 0.0002 in. This really means that cyanide zinc platings are generally more fool-proof for treatment because of their better uniformity, but probably the best electrolytes are the modern bright zinc plating solutions. These give very close grained, dense and lustrous deposits of uniformity rather superior to those from the ordinary zinc cyanide electrolytes.

Passivated bright zinc coatings withstand the humidity tests detailed above without any deterioration

TABLE IX.

Influence of Passivation of Zinc plate upon subsequent enamelling. Shown by mild cyclic humidity test (warm and dry, cool and moist) on enamelled specimens. Finish consisting of one spray coat of semi-gloss white stoved enamel. Total period of test 20 days.

Sample No.	Zinc Plate Electrolyte.	Passivation Process.	Ageing of Stoved Enamel Finish shown by:—			
			Adhesion on bend test.		Adhesion on scratch test.	
			Initial.	After 20 days' test.	Initial.	After 20 days' test.
1	Cyanide.	None.	Excellent.	Rather poor.	Very good to excellent.	Very good.
2	"	Dichromate/Sulphuric Acid.	"	Poor.	" "	Rather poor.
3	"	Chromic Acid.	"	Rather poor.	" "	" "
4	"	Modified Dichromate A.	Very good.	" "	" "	" "
5	"	" " B.	" "	Very good to excellent.	Rather poor.	Very good.
6	Sulphate.	None.	Variable, very good to poor.	Poor.	Variable, very good to rather poor.	Rather poor.
7	"	Dichromate/Sulphuric Acid.	Excellent.	Very good.	Very good.	Rather poor.
8	"	Chromic Acid.	"	Poor.	" "	Rather poor.
9	"	Modified Dichromate A.	Very good.	Very poor.	Very poor.	Rather poor to very poor.
10	"	" " B.	" "	Very good.	Rather poor.	Rather poor.

TABLE X.
Showing method of Assessment of Adhesion of enamel coatings in Tables VIII and IX by behaviour of film on bend and scratch test.

Description.	Bend Test.	Scratch Test.
Excellent.	Finish hard and elastic, no signs of cracks whatsoever along the bend, and cannot be scraped off with thumb nail from the bend.	Finish yields a clean scratch track, with no signs of chipping at ends, along track or at intersection of tracks.
Very good.	Finish shows cracks but does not detach from crack during bending, and is not easily scraped off with thumb nail from the cracks.	Finish shows only slight chips along scratch track or at the ends.
Rather poor.	Finish cracks and becomes detached at the bend or can be easily scraped off from the cracks at the bent area only.	Finish shows marked chipping along the scratch track, or/and at its ends or intersections.
Very poor.	Finish cracks and generally tends to flake off or is easily scraped off with the thumb nail back from the bend.	Finish tends generally to flake off upon scratching.

whatsoever. However, although the bright zinc electroplating processes are extensively operated in America, they are not so universally employed in this country. On the other hand, they have in themselves many advantages. Generally, they are operated at higher current densities than the more orthodox dull deposit producing baths, and are therefore more economic in floor space, plant expenditure and overall overhead expense. Output is secured more quickly and operating expense on a quantity/labour-hour basis is materially reduced. The plated work is much more readily handled without finger-marking, because of the non-absorbent character of the coating, and consistent lustre and colour assures a continued uniform appearance. Further, change of colour and staining do not develop during subsequent storage as they inevitably do with matt zinc platings. Therefore, bright zinc plating, which is advantageous to passivation processes, possesses inherent advantages in other directions which should not be too cursorily passed over.

For space reasons, passivation has been considered in detail from the effectiveness point of view in the foregoing only with respect to electro-plated zinc coatings. On its merits, it can be shown to possess similar advantageous qualities with respect to sprayed zinc coatings as applied by the wire pistol, the powder pistol or the molten pistol processes. Likewise its value can be demonstrated for die-cast zinc components or for galvanised articles or sheet metal work. As for all metal finishing processes, the best method should be chosen for the particular class of work concerned; the plant layout should be judiciously planned to suit the rest of the plant arrangement, and plant capacity must be adequate. All associated operations such as after-washing and drying must be provided for on an adequate scale and efficiently executed. A simple degree of process control with respect to general cleanliness, orderly handling and flow of work, maintenance of solutions and timing, particularly for the immersion in the actual treatment solution, should be instituted. Under such conditions, uniformity of results are assured and no obscure processing troubles will arise to create difficulties. True, some further development is desirable where enamel coatings are involved, but these will, no doubt, materialise in the not too distant future. In the meantime, marked benefits can be secured from passivation processes. Briefly stated, these benefits signify that existing types of zinc coating can be rendered far more durable, and therefore of longer service

TABLE XI.
Laboratory characteristics of enamels employed in tests recorded in Tables VIII and IX.

Characteristic.	Enamel Type.	
	Semi-bright white cellulose enamel.	Semi-bright white storing enamel.
Type	Nitrocellulose base.	Modified Glyptal.
Stoving conditions ..	—	30 min. at 250° F.
<i>Physical.</i>		
Viscosity at 25° C., centipoises	1000	150
Specific gravity at 25° C. ..	1.001	1.031
<i>Chemical.</i>		
Volatile spirit, loss in weight %, 3 hours at 110° C.	65.5	55.4
	34.5	45.6
TOTAL SOLIDS % ..	100.0	100.0
Dilution for spraying ..	2 parts enamel, 1 part thinners.	None

life, to meet exposure conditions especially in open atmosphere and tropical conditions, than has been hitherto possible. In many cases, it is claimed that, what has in the past been regarded as a reasonable thickness of deposit, can be rendered serviceable in a more reliable manner than could be achieved by increasing the thickness of the coating employed by an appreciable amount. The process involved is simple in all respects, viz., plant, space, process, labour and control. In fact, passivation represents an advance, one stage further in the already extensively developed science and art of metal finishing.

British Iron and Steel Federation President-Elect

At a recent meeting of the Council of the British Iron and Steel Federation, Mr. Ellis Hunter was appointed President-Elect of the Federation, to take office in 1946 in succession to Sir Allan Macdiarmid. Mr. Hunter is Deputy Chairman and Managing Director of Dorman, Long & Co. Ltd., and is the first Chairman of British Steel Producers' Conference, recently formed.

A Yorkshireman, Mr. Hunter has had a long association with the iron and steel industry, although it was not until January, 1938, that he joined the board of Dorman, Long & Co. Ltd. Qualifying as a chartered accountant

in 1913, and elected a Fellow of the English Institute in 1927, he became a partner in W. B. Peat & Co., at Leeds and York in 1922.

His activities were principally in connection with the iron and steel trade and the heavy industries of the North-East Coast and he was associated with many developments in this field during the period between the wars.



A Routine Method for the Analysis of Nickel Bronze

By W. T. Elwell, F.R.I.C. and J. McPheat

A method is described for the complete analysis of nickel bronze. The sample is dissolved in a mixture of hydrobromic acid and bromine and the tin volatilised as bromide.¹ After removal of the copper and lead by electrolysis, nickel is determined volumetrically using a solution of potassium cyanide containing silver nitrate.² Tin is determined on a separate portion after removal of the copper with iron, reduction with nickel and subsequent titration with potassium iodate solution.³

THE term nickel bronze has been somewhat loosely applied to certain alloys which, while not amounting to any great tonnage, are of considerable importance in engineering. They find applications in valve trim for use in super-heated steam, and in some designs of thrust- and bearing-rings.

These alloys contain nickel, copper, tin and lead in major proportions and may contain small amounts of iron, manganese and silicon if the alloy is made from secondary material. Alloys of low nickel content are sometimes referred to as nickel-bronzes, but, in general, the following instructions are intended to apply to materials containing between 10% and 60% nickel.

Solution of such an alloy in nitric acid results in an unsatisfactory precipitate of metastannic acid. Further the sample is difficult to disintegrate completely by such an attack. Any such method of "opening up" will invariably leave undissolved or occluded metals associated with the stannic oxide.

In the following method a mixture of hydrobromic acid and bromine has been found useful. It readily dissolves the alloy and removes tin as the volatile bromide. The method is devised and worked on a routine basis using two samples to make the complete analysis. Alternative methods for manganese and iron are included for laboratories where no provisions exist for absorptiometric technique. The procedure outlined has been successfully applied to over 100 determinations.

Special Solutions

Potassium Cyanide/Silver Nitrate.—Dissolve 20 gms. potassium cyanide in water and add a solution of 0.15 gm. silver nitrate. Dilute to 1 litre with distilled water.

Standard Nickel.—Dissolve 0.8 gm. pure nickel in 50 mls. nitric acid (1:1). Dilute with distilled water, boil free from nitrous fumes, cool and make up to 1 litre with distilled water.

Deci-normal Potassium Iodate.—Dissolve 3.567 gms. dry AnalR reagent in water containing 1 gm. sodium hydroxide; add a solution of 10 gms. potassium iodide and dilute to 1 litre. This solution when carefully prepared should not require standardisation.

$$1 \text{ ml. } \frac{N}{10} \text{ KIO}_3 = 0.00594 \text{ gm. Sn.}$$

If necessary the solution may be standardised against AnalR tin under similar conditions to the determination.

Procedure

Silicon, Copper and Lead.—Transfer 1 gm. sample to a squat beaker and dissolve in a mixture of 25 mls

AnalR hydrobromic acid (sp. gr. 1.46) and 3 mls. AnalR bromine. Remove the cover-glass and evaporate slowly to dryness. Cool and repeat the operation by the addition of a further 10 mls. mixed reagent. Bake at a moderate temperature for 15 mins. Cool, add 25 mls. nitric acid (1:1) and boil well to remove free bromine. Filter, wash well with hot water and determine the silica by volatilisation as tetrafluoride. Calculate to silicon.

$$\text{SiO}_2 \times 0.467 = \text{Si.}$$

Electrolyse the filtrate and washings for half an hour at a current density of 1 amp. per sq. dm. to remove lead. Add 10 mls. sulphuric acid (1:3) and complete the deposition of copper. Test for completeness of removal of metals by lowering an unplated portion of the electrode stem into the solution, alternatively wash the cover-glass and sides of the beaker with a fine jet of water from a wash-bottle. When electrolysis is complete quickly remove the electrodes by lowering the electrolyte and wash by immersion in a bath of distilled water. Rinse the cathode thoroughly in two successive baths of methanol. Dry at 110° C. for 5 min., cool and weigh the metallic copper. Rinse the anode thoroughly with water and dry at 110° C. for 15 min. The increase in weight is due to PbO₂. This deposit is fragile and must be handled carefully.

$$\text{PbO}_2 \times 0.866 = \text{Pb.}$$

In the presence of substantial amounts of manganese (excess of 1%) this element will be partially co-deposited at the anode. In this case, where extreme accuracy is required, remove the lead by solution in 20 mls. nitric acid (1:4) containing 1 ml. 10% sodium nitrite. Determine the lead by conversion to sulphate or molybdate.

$$\text{PbSO}_4 \times 0.683, \text{ or } \text{PbMoO}_4 \times 0.564 = \text{Pb.}$$

Nickel, Iron and Manganese.—Bulk the electrolyte and aqueous washings from the previous determinations; dilute to 500 mls. and mix thoroughly.

Transfer 250 mls. to a suitable beaker and add twice the amount of tartaric acid necessary to prevent precipitation in ammoniacal solution (circa 10–20 mls. 25% solution). In the absence of group III metals, tartaric acid may be omitted. Add ammonia solution (sp. gr. 0.92) until the odour is slight but distinct. Excess of free ammonia has a disturbing influence; a large excess hinders and may entirely prevent the reaction.

After addition of a few drops 10% potassium iodide solution titrate with the potassium cyanide/silver nitrate solution at a temperature not exceeding 20° C.,

¹ *Chem. and Ind.*, 1934, 53, p. 615.

² "Sutton's Volumetric Analysis" (12th Edn.), 1935, p. 293.

³ *Ind. and Eng. Chem. (Anal. Edn.)*, 1943, 15, p. 261.

adding the cyanide slowly with constant agitation. A suitable titration is between 30 mls. and 50 mls.

Silver iodide is precipitated and the turbidity thus produced increases to a point when formation of the nickel-potassium-cyanide complex is complete. Any further addition, after this stage is reached, diminishes the turbidity until addition of a further drop causes it to vanish. This end point, which is sharp to within ± 0.1 ml. is best observed against a black background.

Calculate the nickel content using an empirical factor for the cyanide solution.

Standardise the cyanide solution under conditions identical with those of the determination using a volume of standard nickel solution which will give approximately the same titration. If a 250 mls. aliquot of the standard nickel solution is used the bulk conditions will be automatically adjusted. It may be convenient to adjust the strength of the standard nickel solution to meet individual requirements.

1 ml. cyanide solution = approximately 4 mg. Ni. Iron and manganese are determined colorimetrically on aliquots of the stock (500 mls.) solution. Details are given for these determinations using a photo-electric absorptiometer such as the "Spekker."

Iron.—To a 50 mls. aliquot add 10 mls. sulphuric acid (1:1) and take to fumes of sulphur trioxide. Cool, add 40 mls. hydrochloric acid (1:3) 10 mls. 1% freshly prepared ammonium persulphate solution and 10 mls. 20% sodium thiocyanate solution. Adjust the volume to 100 mls., shake and allow to stand 15 min. Fill the compensating cell with a solution prepared in exactly the same manner (omit the sodium thiocyanate solution).

Measure the absorption using appropriate sizes of cells and spectrum blue-green filters in conjunction with a tungsten filament lamp (e.g., Ilford Spectrum Blue-Green Filters No. 603) or Spectrum green filters where a mercury vapour lamp is used (e.g., Ilford Spectrum Green Filters No. 604).

Calculate the iron content from a previously prepared graph. **Note.**—The filters recommended for use with the mercury vapour lamp should be separated from the lamp by heat-resisting glass filters, e.g., Chance H.503.

Determine the manganese⁴ on a further 50 mls. aliquot. Add 15 mls. "Spekker" acid⁴ and 0.5 gm. potassium periodate. Simmer for 5 min. in order to obtain complete oxidation to the permanganate stage. Cool, dilute to 100 mls. and shake. Fill the compensating cell with a solution prepared in exactly the same manner (omit the potassium periodate). Measure the absorption using spectrum green filters in conjunction with a tungsten filament lamp (e.g., Ilford Spectrum Green Filters No. 604) or spectrum yellow filters where a mercury vapour lamp is used (e.g., Ilford Spectrum Yellow Filters No. 606).⁵

Calculate the manganese content from a previously prepared graph.

Where the manganese approaches 1% determine by the direct procedure if extreme accuracy is required.

Alternative Procedure for Direct Determination of Iron and Manganese

Iron.—Dissolve 1 gm. millings as previously indicated. When excess

bromine has been removed dilute and precipitate the iron with a good excess of ammonia solution. Boil, allow to flocculate and filter. Wash thoroughly with hot water and return the precipitate to the original beaker. Dissolve the iron from the paper by means of hot hydrochloric acid (1:1). Reprecipitate the iron and finally determine volumetrically with standard potassium dichromate solution.

Express the result as percentage metal.

Manganese.—Use a factor weight of 1.1 gm. and dissolve as previously indicated. After removal of free bromine, cool and proceed as in the normal bismuthate method.⁶ Complete the determination as usual using standard solutions of ferrous ammonium sulphate and potassium permanganate.

Calculate to percentage manganese.

Tin.—This method is a modification of that given in the references^{7, 7 and 8}. The original procedure⁸ has been applied with very good results to nickel-bronze samples. The details given below are preferred where speed is an essential factor.

Dissolve 2 gms. sample in 30 mls. concentrated hydrochloric acid and 2 gms. potassium chlorate. Add the potassium chlorate in small amounts shaking well after each addition. Warm gently to complete solution. The solution at this stage must not be boiled. When the sample is dissolved dilute to 200 mls. with distilled water and boil gently to remove free chlorine. Remove from the source of heat, add 2 drops antimony chloride solution (2 gms. SbCl₃ dissolved in 50 mls. concentrated HCl; diluted to 100 mls.) and 5 gms. pure iron wire made up in spirals. Simmer until all the copper is precipitated. Test for complete removal of copper by adding an additional small amount of iron and observe the reaction.

When the copper is completely removed filter rapidly through a pulp pad washing thoroughly with boiling water. Collect the filtrate in a 500 mls. conical flask and adjust the bulk to approximately 250 mls. Add 50 mls. concentrated hydrochloric acid, 5 gms. sodium chloride and 10 gms. pure nickel shot (approximately 10 mesh). Alternative reduction may conveniently be brought about by means of a nickel spiral made from sheet metal. Fit the flask with a bung and delivery tube passing into a beaker of water and boil the contents of the flask for not less than 30 mins. Several minutes before the end of the boiling period, transfer the outlet tube to a beaker containing saturated sodium bicarbonate solution. Retain the end of the tube below the surface of the bicarbonate solution and cool rapidly in a stream of cold water.

Remove the bung and delivery tube as rapidly as possible and immediately introduce a 2 gms. pellet of

⁶ "Chemical Analysis of Iron and Steel," Lundell Hoffman and Bright, 1931, p. 190.

⁷ "A.S.T.M. Methods Chemical Analysis of Metals," 1943, p. 189.

⁸ *Ind. and Eng. Chem. (Anal. Edn.)*, 1944, **16**, p. 555.

Sample		Copper %	Tin %	Lead %	Iron %	Nickel %	Manganese %	Silicon %
1	Average result of 10 analyses ..	41.25	9.59	5.10	3.21	40.79	0.17	0.02
	Deviation	+0.17 -0.09	+0.09 -0.08	+0.17 -0.18	+0.07 -0.03	+0.16 -0.13	+0.02 -0.01	+0.01 -0.01
2	Average result of five analyses ..	42.50	13.10	6.59	1.80	35.74	0.11	0.01
	Deviation	+0.02 -0.02	+0.07 -0.06	+0.05 -0.11	+0.01 -0.02	+0.02 -0.06	+0.01 -0.01	—
3	Average result of five analyses ..	43.61	10.31	5.50	1.53	38.67	0.17	0.01
	Deviation	+0.05 -0.05	+0.04 -0.03	+0.04 -0.02	+0.01 -0.01	+0.08 -0.14	+0.01 -0.01	—

sodium bicarbonate or solid carbon dioxide. This will provide a blanket of inert gas over the solution. Add 5 mls. starch solution and titrate with the standard potassium iodate solution to a permanent starch-iodide blue.

Calculate to percentage tin.

Results

The following table gives a summary of results obtained on three different samples of nickel-bronze

when the recommended procedure was adopted. The results are an average of a given number of analyses on the same sample. The maximum and minimum deviations from the average are recorded in the accompanying table.

The work described in this paper was carried out jointly in the Laboratories of Imperial Chemical Industries (Billingham Division) and G. and J. Weir, Ltd., Cathcart.

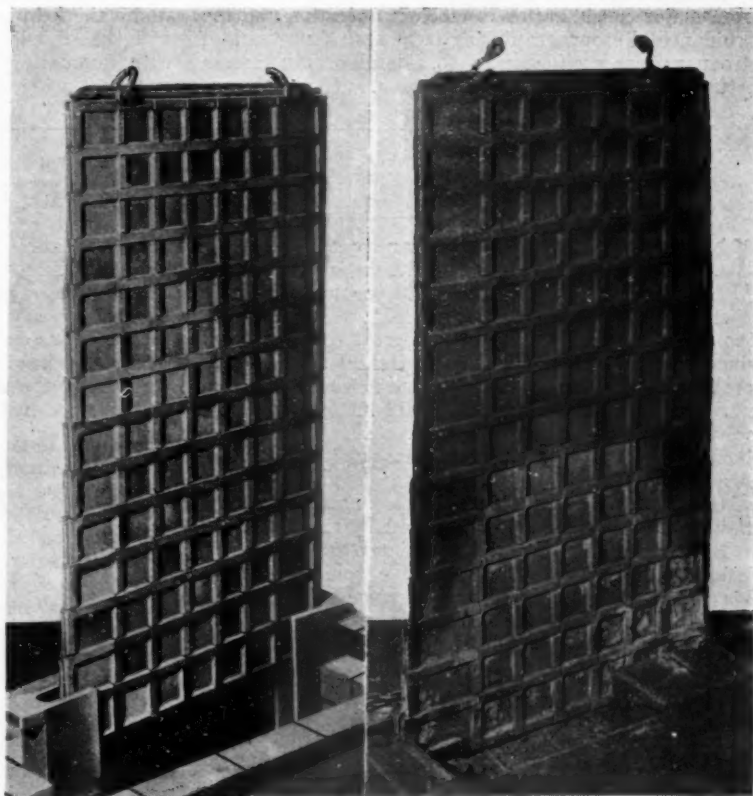
The "Javelle" System of Heat-Resisting Units for Furnace Damper and Hearth Construction

IT is not sufficiently realised that in the successful operation of every type of furnace the damper is one of the most important items of the auxiliary equipment. As the principal means of controlling the flow of gases the damper regulates the rate of heat admission to the furnace, and is the prime agent, not only for determining whether the character of the heating is satisfactory, but also for ensuring that the utmost efficiency is obtained from the fuel.

Fuel is wasted if the rate of firing cannot be correctly adjusted, or if leakage of cold air into the furnace is permitted, and in many cases these factors are almost entirely governed by the position and fit of the damper. Well fitting dampers, in good state of maintenance, easily operated, and capable of fine adjustment, are thus an essential feature of successful furnace operation.

In the past, dampers have usually been constructed of steel or iron plates, or of firebricks, supported and reinforced by a steel or iron framework. Where the temperature of waste gas is high, such dampers speedily become burnt and warped, bricks fall out, and satisfactory operation becomes impossible. Similarly, fluctuating temperatures, giving rise to repeated expansion and contraction, set up distortion and the same difficulties arise.

A ready means of overcoming these difficulties has been introduced by Hadfield's Ltd., using a new type of damper, constructed according to the "Javelle" system.* This consists of units of heat-resisting steel in plates or blocks which are provided with a special type of joint so that they may be built up in the required form. These joints are so designed that, while preventing the leakage of gases, they allow sufficient movement of the individual elements to permit of



Damper installed in 1940.

Damper after 3½ years' continuous service.

repeated heating and cooling without loss of shape and consequent fouling of the guides. Hadfield's "Era" heat-resisting steels are used, the grades varying in accordance with the working conditions involved and dampers can be furnished which are capable of withstanding the highest flue temperatures normally met with in furnace practice, i.e., in the range of 1000/1100° C.

The advantages resulting from the use of these "Javelle" dampers are strikingly illustrated by the case of a certain large forging plant. The furnaces of this plant are fired by pulverized coal and the normal

* Patent No. 514396.

type of fire brick damper, supported by an iron framework, was proving unsatisfactory in operation and expensive to maintain in an efficient condition.

A "Javelle" damper was installed in October, 1940, and after four and a half years' service the responsible engineer reported:—

"This damper has been in my service ever since it was installed and has proved very satisfactory, costing nothing for repairs, giving no trouble, and is still good for further service."

The fire-brick dampers had proved to be very costly in repairs owing to the particularly severe conditions, which entailed waste gas temperatures of 750/800° C. and even higher, coupled with the passage of flame into the waste gas flue when downtakes from the furnace chamber were becoming choked, with the accumulation of dust and sinter inseparable from the use of powdered coal.

The economics of this case are interesting, since apart from major consideration of efficient operation and the avoidance of stoppages during more than four years of strenuous war production, a considerable reduction in actual damper costs has been recorded. The brickwork

dampers cost, in repairs and maintenance alone, £70 per damper, per annum, the principal divisions of expense being:—

Bricks	18%
Ironwork	58%
Labour	24%

On this basis the "Javelle" damper has already shown a saving of nearly 200% on its initial cost, or in other words, its cost was fully covered within a period of seventeen months, without taking into consideration the important economies resulting from continuous and trouble-free operation. Present indications are that this damper promises to last indefinitely and the success of this extended trial has resulted in orders for the replacement of all fire-brick dampers in this plant by these dampers.

The "Javelle" system of built-up units is also admirably suited to the construction of furnace hearths where the heat-resisting qualities of the units, coupled with their freedom to expand and contract in accordance with fluctuating temperatures, ensure long and satisfactory service with a minimum of maintenance.

The Position of Metallurgists in Russia

INFORMATION reaching this country regarding the position of metallurgists in Russia is very small; indeed, it is almost impossible to obtain Russian scientific or technical publications from which to review the progress of metallurgy in that great country. Yet, since the industrialisation of the U.S.S.R. tremendous problems have been encountered and it is apparent that many great problems in the field of metals have been solved in a satisfactory manner. It is noteworthy, therefore, that Ivan Bardin, vice-president of the Academy of Sciences, speaking at the 220th anniversary of the Academy, should have directed particular attention to the place of honour occupied by metallurgists.

He referred to that genius of the 18th century, Mikhail Lomonosov, who applied the achievements of his day to metallurgy and was responsible for the first Russian scientific text-book on metallurgy, in which he laid down the fundamentals of quantitative analysis and anticipated a hydro-dynamic theory of gas flow, so important in designing metallurgical furnaces.

After Lomonosov the Academy went counter to the ideas of Peter I, its founder, and for a long time it was engaged primarily in abstract science. Hence, a number of important researches influencing the development of metallurgy were conducted outside its walls. Among these were the brilliant investigations of Musin-Pushkin, Sobolevsky, Lyubarsky, Bagration and others which won world recognition.

Triumph for Russian science was the work carried out in the second half of the 19th century by Mendeleev and Chernov. Mendeleev, discoverer of the periodic law of the elements and father of new chemical theories, not only shed light on the nature of physico-chemical processes in metallurgy, but did a great deal towards solving the practical and economical problems facing the Russian metal industry. Chernov's work was of tremendous importance in the development of steel production and particularly of high-grade steels.

In pursuance of a Government decision a section of Technical Sciences was established in the Academy in 1932, which set up a framework for fruitful collaboration between theory and practice. Since that time the Academy has conducted work in close contact with industrial research organisations and factory laboratories. In the Academy itself there were established institutes of metallurgy, mining, power, fuel, etc.

During the two Five-Year Plans in the 30's the iron and steel industry was reconstructed from top to bottom and grew four times as large as it had been in 1913. It solved difficulties associated with the production of many special steels and learned to meet the most exacting demands of the engineering and defence industries. A good share of the credit for these achievements goes to the following members of the Academy: N. Kurnskov, who made a major contribution to the physico-chemical fundamentals of metallurgy; A. Baikov, who evolved the original theory of metallurgical processes that promoted the development of non-ferrous metals and manufacture of special steels; M. Pavlov, one of the world's biggest blast-furnace specialists; N. Chizhevsky, for his work in obtaining high quality fuel from low grade coal; N. Gudstov, an outstanding expert on special steels; E. Britske, who made an incalculable contribution to smelting ores containing titanium and vanadium. Outstanding among Soviet geologists who made available new sources of raw material is Academician V. Obruchev, Hero of Socialist Labour, known for his investigations of the mineral wealth of Siberia.

Apart from helping to equip the U.S.S.R. Army with all the requisites for victory, the Academy staff helped to solve involved problems connected with transferring metallurgical industry from German occupied districts to the East, found new types of raw materials to replace those temporarily lost, and promoted the production of alloy steels in shops built for handling ordinary steel.

The Iron and Steel Institute

Seventy-Sixth Annual Meeting in London

Although this meeting was originally fixed for May 9 and 10, and postponement was necessary, because of victory celebrations, the rearrangement to July 11 and 12 did not appear to have diminished the attendance of members and friends. The spirit of the meeting was high and in this respect approached pre-war meetings. Brief reference is made to the business meeting and to the discussions at the technical sessions.

THE seventy-sixth annual meeting of the above Institute, postponed from May 9 and 10, was held at The Institution of Civil Engineers, on July 11 and 12, 1945 with the president, Mr. Arthur Dorman, occupying the chair. Members of the Institute of British Foundrymen had been invited to take part.

Following the presentation of the minutes of the previous meeting the president made fitting reference to the deaths of two past presidents: Mr. W. R. Lysaght, C.B.E., who died on April 27, and who was regarded as a Grand Old Man of the industry and a great friend of many members of this Institute; and Sir William H. Ellis, G.B.E., D. Eng., who died a few days ago. Both men did yeoman work for the iron and steel industry.

The president offered a cordial welcome to all the members and visitors present; he expressed pleasure at the presence of many Americans and also offered a warm welcome to Mr. M. Tigershiöld, a Swedish engineer who was present at the Institute's Council meeting.

Report of Council

The Report of the Council for 1944 shows a considerable increase in membership and several comments on it were made by the president. He directed particular attention to the services of the Institute's staff and mentioned that Mr. Elsdon, librarian, has completed 40 years' service; Miss Dowd, accountant, and Miss Davidson, assistant librarian, 25 and 26 years, respectively; and Mr. Chattin, assistant secretary, 20 years.

Co-operation with the Institute of Metals. Friendly co-operation which has so long characterised the Institute's relations with the Institute of Metals has continued. A good deal is being done to secure closer working together of the two Institutes.

Local Societies. Many joint meetings have been held with local societies. A new development of considerable potential importance is the affiliation arranged with the Lincolnshire Iron and Steel Institute, the Sheffield Society of Engineers and Metallurgists and the Staffordshire Iron and Steel Institute. We expect that similar affiliation will be arranged with other societies. The Council feel that some part of members' subscriptions should be spent in the districts in which they live and work, and that it is much better to make use of well-established local societies than to compete with them by forming local branches. These local societies have their own traditions and local enthusiasms, and some of which are older than this Institute; they should remain independent, and it is believed that affiliation will effect mutual help.

Proposed Institution of Metallurgists. Some months ago, a preliminary notice was given of the steps taken by the Council, jointly with the Council of the

Institute of Metals, to encourage metallurgists to form a professional institution. It is expected that the new institution will be registered very soon, and that applications for membership will be invited. Joint membership rates have been agreed, and this should be helpful. The Council believe that by encouraging its formation something of real value for professional members has been done. We wish the new Institution of Metallurgists every success.

National Certificates in Metallurgy. Not unconnected with the above is the recent formation of a Joint Committee for National Certificates in Metallurgy, on which, in addition to representatives of this Institute, there sit representatives of the Ministry of Education, the Institution of Mining and Metallurgy, and the Institute of Metals. A full explanatory memorandum is being issued to all members. It is hoped that the principals of technical colleges in all suitable districts will encourage their pupils to join courses, and that employers will give practical encouragement to young men on their staffs to work for these certificates. This is an important step in spreading knowledge of the science on which industry is based.

Research. The president also referred to the new British Iron and Steel Research Association which has been formed by the British Iron and Steel Federation to take over responsibility for co-operative research, and for which the Federation has agreed to set aside a substantial annual sum for its work. The Institute nominates nine members of the Council of the new Association. It is proposed that our Joint Research Committees, which have done so much during recent years for research, shall continue, and that each shall be responsible to the appropriate divisional panel of the Association. The Institute will be glad to give all possible other help to the Research Association, notably by making available library and information services and by publishing reports.

Portrait of Mr. James Henderson

The president announced to the meeting that, during the previous evening, a portrait of Mr. James Henderson, past president, by Oswald Birley, was presented to the Institute by Sir Walter Benton Jones, Bt., on behalf of the Board of the United Steel Companies, Ltd. In making the presentation Sir Walter referred to the great services Mr. Henderson had rendered to the industry and to the Institute over a period of fifty years, in the course of which he had held almost every possible position of influence and authority and lent distinction to them all. Sir Walter said his company regarded it as a pleasure to be able to make the presentation. He also paid tribute to Mrs. Henderson and congratulated the artist. From the volume of applause there was no doubt about members endorsing these views.

Presentation of the Bessemer Gold Medal

In presenting the Bessemer Gold Medal to Mr. Harold Wright, the chief metallurgist of Dorman, Long and Company, the president said: "Having known Mr. Wright for forty years, it is a great pleasure to be in the chair at the time when he is to receive this honour, the greatest the Institute can bestow. My meeting with him was forty years ago, and we were struggling at our Britannia Steelworks, using molten Cleveland iron in the basic open-hearth process. The furnaces were too small and the iron was what might be called patchy. Mr. Wright, who was then the chief chemist at Samuelsons, was very helpful to us in our difficulties; he induced Mr. Samuelson to improve the quality of the iron by additions, first of Swedish and then by other ores, with the result that we obtained quite a good basic iron and made much better progress with this more or less new molten metal process. In those earlier days hardly any scrap was used; only iron oxide was put in the furnace and the molten metal poured in, and, as can be imagined, the reactions were considerable.

"Mr. Wright's activities included by-product coke ovens. Samuelsons were one of the first to instal by-product coke ovens. He saw the waste of a million cubic feet of gas a day and he made suggestions for utilising it. The town authorities were a little suspicious, and difficulties were probably magnified. In 1913, however, Middlesbrough became the first municipality to utilise coke-oven gas, and this was due entirely to the sustained efforts of Mr. Wright.

"In 1918 Mr. Wright became chief metallurgist to Dorman Longs where, at first, he gave his chief attention to coke ovens and blast furnaces, but he was soon switched over to the steel side in addition. He was very helpful in assisting the steel furnace managers in making the special steel required for the Sydney Harbour Bridge a number of years ago. But the outstanding feature of Mr. Wright's career is that he has been a real and true friend to any manager in trouble. Even to-day, though no longer so young as he was, he will lend a helping hand to any manager whose blast furnace or steel furnace is causing him a little trouble. His practical experience is enormous and he takes a worthy place in the list of famous men who have had this honour conferred upon them."

Amid applause the president handed a replica of the Medal to Mr. Wright.

Mr. Wright, in accepting the award, said he had spent the whole of his life in solving those urgent, practical problems that the works managers meet with in their daily life, and almost in their hourly life. Starting many years ago, for ten years at least at the North Eastern Steelworks, he was personally responsible for investigating every defect that occurred in connection with the steel. That is very important work, which has to be carried on at all steel works. He must not be understood as saying anything which would seem to minimise the importance of long-term research, but this work which he had been doing has been and will continue to be essential to the progress of the industry.

Continuing, he said his work had to a large extent kept him from being associated with other activities. Before the present war, his firm was producing 30,000 tons of steel ingots a week, which brought problems to people like him, and with collieries, mines, sheet works, and constructional activities, including bridge-building,

all of which have furnished problems, a tremendous amount of work was involved in solving the day-to-day problems. In all his work he had been assisted by colleagues, and had had the help of the firm's large staff of very excellent analysts and other scientists, who had helped him. In addition to that, he had received the greatest help from Mr. Arthur Dorman and from the other directors and the executive. He had been helped by the firm in every new undertaking that he had brought forward. In expressing thanks, therefore, for the great honour, he felt that he must give part of the credit to those who had helped him.

Williams Prizes

The president announced the decision of the Council to award the Williams Prize for 1944 to Mr. G. D. Elliot, of the Appleby-Frodingham Steel Co., Ltd., for Special Report No. 30: "Iron Making at the Appleby-Frodingham Works of the United Steel Companies, Ltd." The president said Mr. Elliot richly deserves this Prize and had great pleasure in handing it to him.

A further award of a Williams Prize was made to Mr. R. W. Evans, of Guest, Keen and Baldwins Iron and Steel Co., Ltd., for his paper on: "The Heating of Open Hearth Furnaces with Mixed Coke Oven and Blast Furnace Gas."

Officers and Council

At the meeting of the Council Dr. C. H. Desch, F.R.S., was nominated as president for next year. In recognition of his long and distinguished service to the Institute, Sir Peter Brown was appointed as honorary vice-president. Professor Thomas Turner was also elected an honorary member of the Institute. The existing vice-presidents and members of Council were re-elected. They are:

Vice-Presidents: Dr. C. E. Desch, F.R.S.; Captain H. Leighton-Davies and Mr. J. S. Hollings, C.B.E.

Members of Council: Mr. D. R. Lysaght, Mr. H. H. Rollason, Mr. E. J. Fox, Mr. J. Sinclair Kerr and Mr. J. Mitchell.

The following are now honorary members of Council in their capacity as presidents of the following Societies:

Mr. C. A. Julius Behrendt (Lincolnshire Iron and Steel Institute) in succession to Mr. J. N. Kilby.

Captain H. Leighton-Davies, C.B.E. (Swansea and District Metallurgical Society) in succession to Mr. O. J. Thomas.

Mr. A. A. Munro (Sheffield Metallurgical Association) in succession to Mr. R. Staton.

Technical Sessions

Several papers were presented at this meeting, two being presented at the morning session immediately following the business meeting. Of these considerable discussion resulted from Mr. R. Jackson's paper on "The Applications of Radiography to the Improvement of Foundry Technique." That the subject is of great interest to all associated with the production and use of castings was indicated by the comments made on this excellent paper. Contributors to the discussion included: Dr. F. C. Lea, Dr. L. Mullins, Mr. W. H. Salmon, Mr. N. H. Pemberton and Mr. G. M. Michie. Space does not permit presenting the somewhat lengthy discussion, but brief reference may be made to comments by Mr. Pemberton, who had been asked to refer, in the absence of Dr. Dorey, chief engineer and surveyor of

Lloyds Register, to the significance of the subject to the engineering and steel foundry industries.

As chairman of a committee which is engaged in producing, or trying to produce, radiographic standards for welding, Mr. Pemberton said he was specially interested in the author's method of standards of references, and it seemed to him to be an ideal way of representing the results of radiographic examination, particularly for those who are not able to interpret the actual negatives. The use of radiography is at present in an early stage of development so far as steel foundries are concerned, but Lloyds Register have had some twelve years' experience of X-rays for the inspection of welding, especially in pressure vessels, and, as a result of this experience, he sounded a warning that as the use of X-rays increases in industry there is likely to be a corresponding increase in the number of people wholly untrained in the subject who will nevertheless have the final authority to accept or reject a casting as a result of X-ray examination. Lloyds Register have found it necessary to have surveyors specially trained in the interpretation of radiographs, and the procedure has been amply justified by the results.

In his view, Mr. Pemberton continued, the value of X-rays in the steel foundry is not so much in the routine inspection of castings but rather in the working out of foundry technique. Once a satisfactory technique has been established by means of X-rays, only a check X-ray examination on selected parts, and perhaps on selected castings, need be carried out during subsequent production.

The value of this radiographic procedure may be completely destroyed if the radiographs have to be judged by someone with an inadequate knowledge of radiography, both in the taking of the photographs and in the processing of the negatives. In this connection, he thought that some emphasis should be given to the author's words to the effect that interpretation does not of itself enable a decision to be made as to the suitability of a certain casting for a particular function, the answer to such a question being a problem for the engineer and the designer. These are words which should be carefully weighed. No engineer would be justified in surrendering his right to accept or reject a casting to a radiographer, but that is not to say that the engineer should usurp the functions of the radiographer by interpreting his radiographs for him.

With this in mind, he had been authorised to say that Lloyds Register of Shipping recognises the trend to make greater use of X-rays in engineering as a method of non-destructive testing which can be applied to materials, castings, welds and all kinds of mechanical and electrical assemblies. So far as the Society is concerned, the advances being made in marine, oil and electrical engineering, involving higher temperatures and pressures and more arduous conditions of service, call for an increasing degree of inspection, and in appropriate circumstances there need be no hesitation to make use of available X-ray facilities.

Foundry Practice

The second paper comprised the First Report of the Foundry Practice Sub-Committee of the Steel Castings Research Committee and consisted almost wholly of experimental data representing the experiences of several workers in the study of feeding steel castings. In opening the discussion Mr. H. T. Angus thought the

satisfactory examination of the sections by means of fracture or even deep etching would be almost impracticable, and believed it would be desirable, in an extension of the work, for the sub-committee to consider the use of density determinations as well as saw-cuts, X-rays, etc.

Dr. L. Northcott referred to the author's comment that hot steel poured slowly gives less piping than cold steel poured quickly and suggested that for a good surface on the casting metal should be hot and poured quickly, whereas for adequate soundness it should be poured slowly and as cold as possible, so that some reasonable balance was necessary. He suggested, for further work, that the authors should give their experience in chilling or slow pouring or after feeding.

Centrifugal Casting

In presenting the paper on the "Influence of Centrifugal Casting upon the Structure and Properties of Steel," Dr. L. Northcott said: "Since the work described in the paper was completed, a considerable amount of work has been done on the influence of vibration on unrotated ingots, and it has been shown that there is a particular set of vibrating conditions which will give rise to segregate banding. I should say at once that the original purpose of these tests on vibration was to reduce the crystal size of the castings, and in some cases that does occur; but under particular vibration conditions not yet fully established—at least, the reasons are not fully established yet—a segregate banding similar to the illustration shown is obtainable."

Opening the discussion, Dr. J. E. Hurst said he was sure of the great importance of this work for two reasons. One being that there has been a very great development of interest in centrifugal casting processes during the war, so that an unbiased, systematic investigation into some of the problems involved is of value. The second because of the light that it throws on the problems of heterogeneity in solidifying alloys—not only steel, but the other alloys which Dr. Northcott has investigated. That is of particular importance at the present time, when we are deeply concerned with these problems of heterogeneity in solidifying metals and alloys.

Continuing, Dr. Hurst made a plea for further investigation and expressed the hope that the authors would be inspired by the work they have already done to endeavour to eliminate many of the complexities which exist in the ordinary centrifugal casting process and practice.

Dr. J. H. Whiteley said that after reading the paper three times he was still in complete darkness as to how to explain the curious structure of the steel given. He was still of the opinion that steel, before it begins to freeze, begins to segregate; that is to say segregation starts in the liquid state. That is a possible explanation of the curious results obtained by the authors.

Several other members joined the discussions, including Mr. M. M. Hallett, Dr. E. W. Fell, Dr. W. F. Chubb, and Dr. Northcott replied.

Lead-bearing Steels

The effect of lead additions to steel in improving its machinability is a well established fact based on a large number of reports from actual users, since the introduction of this type of steel in 1938. It is not surprising, therefore, that considerable attention has been given to many aspects of these steels and amongst the papers

presented at this meeting were three published by authority of the Committee on the Heterogeneity of Steel Ingots. The first by Mr. C. S. Graham¹ reports the results of an examination of two ingots of free-cutting steel, one containing lead and the other lead-free, selected from a cast of steel to ascertain the effect of lead addition on the chemical composition and segregation.

The cast consisted of 28 ingots, and the two ingots chosen were the fourteenth and fifteenth in the order of teeming. Both ingots weighed 47 cwt. Samples taken during the teeming gave the following analyses:

	Car- bon %	Sul- phur %	Phos- phorus %	Man- ganese %
At the 3rd mould . . .	0.09	0.29	0.050	1.10
At the 28th mould . . .	0.09	0.28	0.054	1.09

Fifteen pounds of lead shot were added to the metal stream during the teeming of the fifteenth ingot. The addition was started when the metal in the mould reached the 3-in. mark.

Chemical analyses of samples taken from standard positions in each ingot show practically no difference between the chemical compositions of the two ingots with the exception of the oxygen contents, which are slightly of a lower order in the lead-bearing steel. Further investigation will be necessary to determine whether this slightly lower oxygen content has any significance.

Additional lead estimates were made to ascertain its quantitative distribution and the results show the lead to be evenly distributed. Sections of the lead-bearing steel ingot were heated to 700° C. in a reducing atmosphere and in no case was there any lead exudation visible to the naked eye. The only segregation of lead was at the extreme bottom of the ingot. A section taken 4 in. from the bottom was free from segregation. Sulphur prints of each ingot, reproduced in the paper, show less segregation in the lead-bearing ingot than in the lead-free ingot. The only difference of importance found in the macro-structure of the two ingots was a difference in depth of the columnar zone, which was $\frac{1}{2}$ in. less in the leaded ingot.

Condition of the Lead in Lead-bearing Steels

Since the introduction of lead-bearing steels considerable attention has been given to determining the condition in which the lead is present. With this object an investigation has been carried out at the National Physical Laboratory and is reported in a paper by Mr. T. M. Schofield.² This investigation was concerned with the metallurgical examination of six materials, four lead-bearing and two lead-free. Samples were prepared for examination by means of the electron microscope using the technique usually employed at the Laboratory for steels. This consists of rubbing the sawn or filed surface on coarse emery cloth, then on progressively finer grades of emery cloth and paper down to the 00 (Hubert) grade. The 00 scratches are removed on a rotating pad of broadcloth charged with a commercial grade of fine alumina and lubricated with water. The surface is finished on a similar pad, using chromic oxide and water. The chromic oxide is prepared by igniting pure ammonium bichromate.

With this technique all the lead-bearing materials showed inclusions having a rough and mottled appearance, in addition to the inclusions normally present in

steels. As it seemed that the darker and mottled appearance of these inclusions might be due to their partial removal during exposure, a modified polishing technique was employed. The specimens were polished on velvetreen by hand directly from the 00 stage, using specially prepared alumina and water made slightly alkaline by adding a few drops of ammonia solution. The alumina was prepared by slowly heating aluminium sulphate (A.R.) to Seger cone 04A (nominally 1020° C.) in a platinum or silica vessel and cooling in the furnace. Using this modified technique the inclusions appeared white and smooth.

An etching test showed the inclusions to consist of or to contain lead. Polished specimens of the lead-bearing materials were treated for 1 hour in mercury held at 100° C., which removed the inclusions, indicating that these inclusions consist of a metal or metal compound which alloys with mercury. Heating experiments carried out did not provide definite evidence that the inclusions had melted at a temperature just above the melting point of lead.

Occurrence and Distribution of Lead in Lead-Bearing Steels

Relatively little is known about the mode of occurrence and distribution of lead in lead-bearing steel and these aspects of the subject are discussed in a paper by Mr. W. E. Bardgett and Mr. R. E. Lismer.³ The first part of their investigation was confined to the microscopical examination of non-leaded and leaded wrought materials of high-sulphur and manganese-molybdenum qualities and examination of the lead exudation tests by means of a high temperature microscope. The second part consisted of an examination of samples taken from various positions in leaded 0.25% carbon, 1.0% manganese steel ingots with the object of making a closer investigation into the form of existence of the lead and determining its distribution in the ingots.

High-sulphur steels.—A sample of leaded high-sulphur steel (0.18% lead) was compared with a sample of standard high-sulphur quality. The samples were in the form of 1½-in. bar. Inclusions in the standard high-sulphur steel consisted of elongated monophase sulphides, showing a tendency to be streaky, with very occasional duplex oxides-sulphide streaks. In the leaded high-sulphur steel the inclusions were generally similar. Isolated, fairly large segregates of complex non-metallic inclusions were present, which consisted of a dark-grey matrix of silicate containing light-grey globules or particles of sulphide and darker grey particles of cubic form, probably oxide. Etching tests indicated that these segregates contained lead compounds. The presence of lead within the structure, either at the grain boundaries or within the grains, could not be detected.

Manganese-Molybdenum steel.—Samples from leaded and non-leaded ingots of acid open-hearth manganese-molybdenum steel of the following analysis were examined:—

	%		%
Carbon	0.36	Phosphorus	0.045
Manganese	1.43	Molybdenum	0.43
Silicon	0.225	Nickel	0.16
Sulphur	0.032	Chromium	0.11

The ingots were rolled to 4½ × 2½ in. slabs, and samples were taken from the slab discarded from the bottom of each ingot, which, in the case of the leaded

¹ Paper No. 31/1945 of the Committee on the Heterogeneity of Steel Ingots.
² Paper No. 32/1945 of the Committee on the Heterogeneity of Steel Ingots.

³ Paper No. 33/1945 of the Committee on the Heterogeneity of Steel Ingots.

steel, was expected to contain lead segregates. A lead-print obtained by the use of ammonium acetate and hydrogen sulphide solutions, showed that segregation of the lead had occurred to a marked extent in an area $\frac{1}{4}$ in. from the outer surface of the bottom slab. Isolated segregates were evident within the central area of the section. Examination of the non-leaded slab failed to reveal the presence of segregates or streaks of the same type.

Differences were noted in the microstructures of the non-leaded and leaded slabs. The non-leaded was markedly banded and had a coarse Widmannstätten appearance. The leaded slab was only slightly banded; it was more uniform, with no evidence of the Widmannstätten pattern, and the sorbitic pearlite was less dense and more spheroidised. No evidence of the presence of lead within the structure could be detected.

Lead Exudation

The lead exudation was applied to a sample of leaded steel to determine the extent of lead segregation. This test consists of heating a section of the steel at a temperature of 650°–700° C. for a period of 10 min. for each inch of thickness, 2 in. being the recommended minimum thickness. Examination of the behaviour of lead segregates during heating was carried out by means of high-temperature microscopy and a motion film was taken illustrating the actual exuding of the lead. A number of tests were made and recorded, and in each test slight exudation of the lead segregates was observed at a temperature as low as 30° C. Chemical analysis carried out on beads knocked off the surface of a sample heated to 240° C., showed the beads to be of the order of 98–99% lead.

Leaded 0.25% Carbon, 1.0% Manganese Steel Ingots

The second part of this paper deals with an examination carried out on sections from two leaded steel ingots, particulars of which are as follows:—

	75 cwt.	84 cwt.
	22½ in.	23 in.
	cast uphill,	cast uphill,
	narrow end	wide end

Type of ingot	up	up
Carbon %	0.25	0.27
Manganese %	0.88	1.02
Silicon %	0.175	0.145
Sulphur %	0.033	0.032
Phosphorus %	0.032	0.027
Lead %	0.165	0.17

Suitable sections were examined using two methods developed in the Central Research Department of United Steel Companies, Ltd., for detecting the presence and distribution of lead.

Electrolytic etching method.—This method consists of electrolytically etching the section in a solution of ammonium acetate prepared either from the salt or from acetic acid and ammonium hydroxide in the following proportions:—

(a) Ammonium acetate (cryst.)	50 g.
Water to make	1,000 c.c.
(b) Acetic acid (glacial)	75 c.c.
Water	900 c.c.
Ammonium hydroxide (0.880 sp. gr.)	Added until solution just alkaline.

Two alternative procedures may be employed:—

(1) The solution is placed in a stainless-steel bath, attached to the positive terminal of a 6-v. accumulator. The billet section is placed on the bottom of the bath, surface upwards. A platinum wire loop extending across the surface of the section is attached to the negative terminal of the accumulator. The wire is held about $\frac{1}{4}$ in. clear of the base plate. The section is immersed for approximately half a minute.

The position of the lead segregates is marked by the formation of a sharp brown stain over the section through the lead streaks. Heavy rubbing of the surface during drying will result in the partial removal of the stain. The surface should be dried freely after rinsing with water and alcohol.

Electrographic method.—This method of lead-printing was developed before details were received of the excellent method developed by Mr. Wragge (see *Metallurgia*, May, 1945, issue) from which it differs. The procedure adopts the principle of electrographic printing.

Examination of ingot sections by the electrographic method.—Examination of sections from the top, middle and bottom positions of each ingot by lead-printing, electrolytic etching and exudation tests on ground surfaces, indicated freedom from discrete lead or lead-bearing particles. The electrographic method was successful in showing the size and distribution of the lead particles throughout the ingots.

Microscopical examination.—Examination of lead-bearing specimens under the microscope during heating showed that segregated lead in a billet suddenly spurted out on to the surface at a temperature of 235°–240° C., the steel structure being slightly distorted as a result of the exudation. An unsegregated billet showed lead exudation at a higher temperature of 300°–310° C., the distribution of the lead being fairly dense and uniform. In the case of the ingot, the lead spurted out at the still higher temperature of 325°–330° C., corresponding to the melting point of lead. The distribution of the lead on exuding showed a partial interdendritic formation. The size of the exuded lead particles was markedly less in the unsegregated than in the segregated specimens.

It should be noted that bottom-end discards were selected for the examination of massive segregates, the remaining samples being free from such segregation.

Discussion

Mr. J. H. Whiteley thought the second and third papers could be included under one title: "Puzzle: Find the Lead." It is put into the ingot, and what becomes of it no one seems quite to know. Lead is heavier than steel and it is below its boiling point at the temperature of liquid steel, so that one would expect the lead to sink to the bottom of the ingot on solidification. Mr. Graham has shown that there is a slight inclination for the lead to fall, but the difference is so small that it can hardly be said to fall at all. Why it should remain equally distributed in the ingot, no one knows—it is a problem remaining to be solved.

He thought Mr. Schofield had been too modest and complimented him on the beauty of his photographs, considering them the best examples of metallographic work brought before members. There is a difference in the lead particles from the examples of leaded steel by Mr. Schofield and Mr. Graham and he thought this difference to be due to the fact that lead can dissolve

other things out of steel—tin, for example. Tin and lead are soluble, and a chrome acid test may be a test to determine the kind of lead in the steel.

Discussing the third paper, by Mr. Bardgett and Mr. Lismer, Mr. Whiteley asked the authors how it is that they do not mention the constituent found by Mr. Schofield. In all leaded steels that he had examined he had found it. The authors give a great many photographs of inclusions and he asked how these inclusions were identified. One is an oxide, and another a sulphide, yet another lead and another silica, but how do they identify these inclusions?

Dr. N. P. Allen thought the most interesting part of Mr. Schofield's paper was the extraordinary sensitiveness of the appearance of this lead to the way the specimen is polished. Dr. Whiteley says: "Puzzle: Find the Lead." Mr. Schofield's answer is: "Answer: Polish the Specimen." He heartily congratulated Mr. Schofield on his skill and patience in producing the photographs which he has obtained. He thought the constituent obtained by Mr. Schofield had been preserved in the form in which it is present in the steel, and whatever it is, it is a constituent which is freely soluble in hot mercury and is lifted out cleanly from the specimen by his method of mercury etching.

When we come to the question of the identification of the constituent, the position is not quite so simple. Mr. Schofield has described how he tried to find out that the melting point of this metallic constituent soluble in mercury was $327^{\circ}\text{C}.$, and that therefore it was lead, but he could not convince himself that there was a sharp change at $327^{\circ}\text{C}.$, and therefore he had to withhold his judgement on the main conclusion. Messrs. Bardgett and Lismer seem to have been a little more successful with the same experiment; working with different specimens, they seem to have shown in one case that the exudation of the lead occurred pretty precisely at $327^{\circ}\text{C}.$, and if that had been the only experiment done I think we should have been quite satisfied to say that this constituent is simply pure metallic lead, and melts at that temperature; but unfortunately, as so often occurs in experimental work, one does another experiment and gets another result which does not confirm the first; and the authors have another specimen in which the melting point of the exudation occurs at a much lower temperature, $240^{\circ}\text{C}.$

One's first reaction to that is that this must be another constituent of lower melting point, and that possibly the lead, as Dr. Whiteley suggested, has dissolved antimony or tin or some other impurity, and its melting point is lowered thereby. That attitude has been taken, and the analysis of the material is 98% lead, so that that explanation does not seem to work. The authors therefore come back to the explanation that perhaps the lead is extruded in the solid state, in this case where the exudation is taking place at $240^{\circ}\text{C}.$, because of pressures inside the steel; but if that is true it destroys the whole of the evidence, because if pure lead can extrude at $240^{\circ}\text{C}.$ the fact that in the case of the other specimen the extrusion took place at $327^{\circ}\text{C}.$ means nothing; it does not show that that material was pure lead, and so uncertainty still remains. It is possible that different steels contain metallic constituents of different melting points, due to the composition of the constituent not being the same in every case; but that point of view does remain to be established.

In reply Mr. Bardgett said samples that Mr. Schofield used were from the same casts as the ingots included in their investigation. Mr. Schofield had obtained certain results which he and his co-worker did not get. The tests had been carried out as described in the paper and all he could suggest was the need to get together with a microscope and explain their differences; it cannot possibly be done by discussion. Mr. Schofield has confirmed our findings that when there is a lead particle on the surface there is no exudation and no apparent change.

It was intimated that other authors would reply in writing.

The United Steel Companies Ltd. A-Z List of Products

In view of the many difficulties, both as regards paper and production, large firms will find it impossible to revise and bring up-to-date all their technical literature and catalogues for some considerable time. In order to fill the gap during the transition stage, The United Steel Companies, Ltd., have published a list providing an alphabetical reference of products with the names of the constituent companies supplying them.

The list covers the requirements of practically every trade using irons, steel, coal, coal derivatives, and ferrous alloys in almost every form, together with bricks and precast concrete products, etc.

Copies of this list have been distributed in quantity to the following District Sales Offices:

Birmingham—The United Steel Companies Ltd., Union Chambers, Temple Row, Birmingham, 2.

Glasgow—The United Steel Companies Ltd., 120, St. Vincent Street, Glasgow, C.2.

Leeds—The United Steel Companies Ltd., Standard Buildings, City Square, Leeds, 1.

London—The United Steel Companies Ltd., 8-10, Grosvenor Gardens, Victoria, London, S.W.1.

Manchester—The United Steel Companies Ltd., Arkwright House, Parsonage Gardens, Manchester, 3.

Newcastle-on-Tyne—Messrs. Naylor, Benzon & Co. Ltd., 21, Mosley Street, Newcastle-on-Tyne.

Sheffield—The United Steel Companies Ltd., 6, East Parade, Sheffield, 1.

and readers are asked to contact the nearest office for copy of this list.

J. Brockhouse & Co., Ltd. have opened a sales office in Manchester for the purpose of dealing with enquiries and sales for the whole of the Brockhouse Organization covering Northern England. The address is: Eagle House, 30, Cross Street, Manchester, 2. Telephone: Blackfriars 2123-4. Telegraphic Address: "Brockhouse, Manchester."

NORTHERN ALUMINIUM LTD. are opening a chain of sale and enquiry offices for the benefit of manufacturers throughout the country. Arrangements have already been made to deal with enquiries at the Company's works at Middlemore Road, Birmingham. The first of the offices, at 4, Chapel Walk, Manchester, 2, was opened recently and plans are in hand to open others in London, South Wales, the North Eastern Area and Scotland.

The British Iron and Steel Industry

Some Contributions to the War Effort

The manufactures of the iron and steel industry are essential in peace and in war, but the change from peace to war conditions was not a simple operation, especially when it became evident that the flow of production would develop into a spate. From time to time attention has been directed to the war efforts of this industry, but, in view of recent releases of information, further achievements have been revealed which can usefully be recorded, together with some of the difficulties which were overcome in supplying the necessary weight of armour and other important accessories to provide the Forces with arms and equipment to establish victory.

IT has been said that iron is the master metal and when it is considered that cast iron, wrought iron and all steels consist almost wholly of iron the significance of the statement can be appreciated. It is as vital to modern civilisation as air and water are to life and, like air and water, its importance is frequently overlooked. Yet, without underestimating the value and importance of non-ferrous metals, it can be truthfully said that no other metal has contributed so much to the welfare and comfort of mankind. No other metal gives the wide range of physical properties that makes iron suitable for an almost unlimited number of purposes, and it is doubtful whether any other metal has received more study. Unfortunately, practically all the benefits mankind derives from the constant discovery and development of materials can be used to facilitate the destruction of the very comforts sought, and can be used for the wholesale destruction of life itself.

Iron is no exception, indeed, just as it is vital in peace, so is it vital in war. In one form or another it provides the weight of armour necessary in modern warfare to exert overwhelming pressure upon the enemy to bring about a victorious conclusion. It is not surprising, therefore, that on the outbreak of war the importance of Britain's iron and steel industry was quickly appreciated. It is well-known that this country was very inadequately prepared for a war of such gigantic proportions as that with Germany, and the iron and steel industry was called upon to produce its maximum to provide the iron and steel necessary to build up the overwhelming weight of armour to combat such a foe.

In changing from peace to war conditions, many problems were almost immediately encountered. The deposits of rich iron ore in this country had become practically exhausted and for many years rich iron ores have been imported from abroad to mix with leaner home ores available. With the increased intensity of submarine warfare, available shipping was used for other purposes and imports of rich ore dwindled until it reached a negligible tonnage and the lean home ores had to be used almost exclusively.

It will be appreciated that, as with coal, deposits of iron ore are not inexhaustible and in all countries in which deposits are mined the tendency has been to mine the richer, more readily accessible and easily reducible ores and to neglect the leaner ores. Thus, in countries like Britain, where the industry has flourished for centuries, the richer haematite home ores are almost exhausted. In countries like America, which have great deposits of rich ores available, the same problems are

not encountered. In that country no difficulty is experienced in obtaining uniform supplies of ore with an average iron content of 50%. Britain's iron ores by comparison are lean and do not exceed an average iron content of 30%, indeed the bulk ranges from about 19 to 27%, and supplies are not by any means uniform, either in composition or in particle size, thus, beneficiation is usually carried out to concentrate the home ores, while large lumps are reduced to a convenient size and mixing and grading is generally necessary to assist the production of an iron of uniform quality.

In addition to the enforced use of lean home ores, involving the handling and transporting of larger tonnages and the charging of burdens, which gave less returns from the blast furnace, fuel is considerably increased in price and more is necessary per ton of iron produced than under normal peace conditions. Since the crude iron from the blast furnace supplies the main tonnage for steelmaking, the effect of these difficulties must be to increase the cost of manufacturing steel. In the steel plants difficulties have also been encountered in providing suitable alloying elements or in substituting available alloys necessitating changes in practice. It soon became essential to make the best use of the tonnages of alloying elements available and to apply the alloys as effectively as possible according to the incidence of availability.

In Britain we had all the coal we required, we could use leaner iron ore, and 15% of our requirements of ferro-silicon from home sources. All the remaining requirements had to be shipped from abroad. Thus, for instance, 93% of manganese ore, 65% of chrome ore, 87% of nickel and 63% of tungsten were from Empire sources and were available to us, providing we could ship from the countries supplying them. On the other hand, we lost about 20% of our chrome ore from Greece; 32% of magnesite which also came from Greece; 89% of our ferro-chrome from Norway and Sweden. We also lost about 57% of our ferro-silicon, 71% of our titanium ore, and also 22% of tungsten, which came from China. Supplies of these materials that were available had to be controlled, but under the severe conditions then prevailing for cargo ships, supplies could not be maintained with the same regularity as in peace time. Considerable modifications in steel manufacture, therefore, were necessary and specifications were substantially reduced.

While steelmakers were faced with the problems of using unfamiliar materials and making steels to meet new specifications the demand for more steel was insistent; every plant was brought into operation in an



Fig. 1.—British sappers erecting a Bailey bridge over the Arno. The former bridge was destroyed by the Germans.

effort to satisfy the demand. Thus, while considerable modernisation of plants had been carried out before the war, the more obsolete plants were utilised to ensure a greater production.

When it is realised that steel furnaces have been worked regularly beyond their normal capacity, under black-out conditions and with frequent alerts and these are considered in relation to the success achieved, there can be few who believe other than that the British iron and steel industry has given a good account of itself. While the normal production of British steel plants before the war was between 10 and 11 million tons, it is probable that, when figures become available, production during the peak year, 1943, will be nearer 14 million tons.

But while the iron and steel industry is primarily concerned with the basic processes of coke manufacture, iron smelting and steelmaking, it includes many other operations embracing castings, forging, plate, sheet and strip rolling, tube making, wire drawing, wire and net weaving, structural work, and much additional work on to the fringes of mechanical engineering. In addition, must be included the alloy and special steels for conversion into the various tools, components and the numerous forms of armour and armament.

While the production of guns of various calibre, tanks, and the multitudinous forms in which steel is required for war purposes has been greatly augmented by various sections of the industry, its great experience has been invaluable in carrying out many operations and in building structures considered to have been impossible. Mention may be made of the Bailey Bridge, the Tank

and Scissor Bridges, which served our Forces so admirably, especially in Italy, where the terrain is difficult. The colossal task of planning and constructing a prefabricated floating harbour, big enough to supply the Allied Armies in France. Huge concrete caissons, each weighing 7,000 tons, were towed across the 100 miles of Channel and set down at Arromanches, on the Normandy coast, where 15 obsolete ships had been sunk to form a preliminary harbour arm. Floating piers and pierheads were made in sections and towed across the sea. These structures enabled the Allied Armies' demands for supplies to be met. Another valuable contribution was the pipe line under the ocean, which enabled the Allied Armies to receive supplies direct instead of by ship transport.

It is of interest to give in outline some indication of the contributions made by a few representative iron and steel firms. The complete story would probably fill a good-sized book for each firm, but a brief summary will suffice to show that the industry has spared nothing and no-one to provide the iron and steel and services needed to hasten the victory achieved.

Contributions of Representative Plants

During the war years Colvilles Ltd. have rolled over 9 million tons of steel. This steel was produced in many forms. In this group of works is the largest plate mill in Britain and a section mill which is claimed to be the largest in this country. The plate mill at Clydebridge has the European record for the greatest out-put of plates in one week. At the other mills in this group are a number of mills capable of producing a great variety of steel products.

Colvilles supplied all the steel required for several battleships, for a number of cruisers, aircraft carriers, for torpedo boat destroyers, frigates and corvettes, minesweeping vessels, as well as large quantities for landing craft. In addition, they maintained steady supplies for the building of ships for the Merchant Navy required as oil tankers, transports and for the carrying of food. They produced thousands of tons of shell steel every week—from the smallest size required in aircraft to those for the larger guns, and were called upon to make the largest size of bombs required for aircraft, including the 12,000 and 20,000 pounders, of which they produced regular weekly supplies. Many thousands of tons of steel were rolled for the Bailey Bridges and for the great floating harbour, known as "The Mulberry," and maintained almost daily supplies of steel for the railways, for road transport, as well as for coal mines and very large quantities for the construction of Tanks.

At the Clyde Alloy Works, Colvilles were able to fulfil their promise to the Ministry of Aircraft Production by producing large quantities of the highest class of steel for aircraft. At these Works, they had the services of a new mill, which they had commenced to erect before the outbreak of war. This mill is claimed to be the most modern of its type and, indeed, its capacity has proved greater than the demand, but it is well fitted to produce alloy steel bars economically, the steel being produced in electric furnaces both of the arc and high frequency type.

At the Hallside Works of the Steel Company of Scotland Ltd., and also at Clyde Alloy Works, Colvilles have foundries capable of making both light and heavy steel castings, which were constantly producing special castings for the Naval and Merchant Fleets. Their Subsidiary, The Fullwood Foundry Co. Ltd., has an up-to-date organisation for the production of ingot moulds and general castings, such as are required for engineering purposes. In addition, the by-product recovery plant at the coke ovens proved a valuable asset to the Nation by being able to supply materials for the munitions of war in a variety of forms and also helping agriculture by the steady production of sulphate of ammonia.

In 1941, there was an acute shortage of plates and Colvilles entered into an arrangement with the Ministry of Supply to remodel one of the plate mills at the Blochairn Works of The Steel Company of Scotland Ltd., to increase its capacity. The scheme involved an outlay of over £1,000,000, and was carried through with practically no stoppage of production. The cogging mill and plate mill at these works have been brought right up-to-date and they have proved thoroughly successful.

The whole of Dorman Long's activities were directed to meet war requirements from the first day of the conflict. Much of the production was in normal peace time form, but there were also many variations—steel to special specifications and for novel weapons. Main production in the five years ended September 30, 1944, included 6,500,000 tons of steel ingots, 16,000,000 tons of coal, 8,750,000 tons of ironstone and 1,500,000 tons of limestone.

Finished steel was supplied for a wide variety of structural work, bridges, ships (plates, sections and prefabricated components), Bailey bridges and shells. Dorman Long carried out many important structural contracts for the Government, large numbers of aeroplane hangars, many new factories and extensions, bridges to facilitate military traffic, a jetty in Iceland and a floating dock with a lifting capacity of 17,000 tons at Durban, South Africa. Another, but smaller, floating dock, for Durban, is also under construction. Nearly 250 tank landing craft and other types of vessels for amphibian operations have been built.

Probably the most spectacular achievement of Dorman Long was the completion of the "Whales" or pierhead equipment of the "Mulberry" invasion harbours. In April, 1944, the Company were asked to accept the responsibility of co-ordinating this work which was then transferred from military to civilian personnel. Following an appeal to the whole of the structural steel industry this vital task was put in hand under the executive direction of the Company's constructional officials and

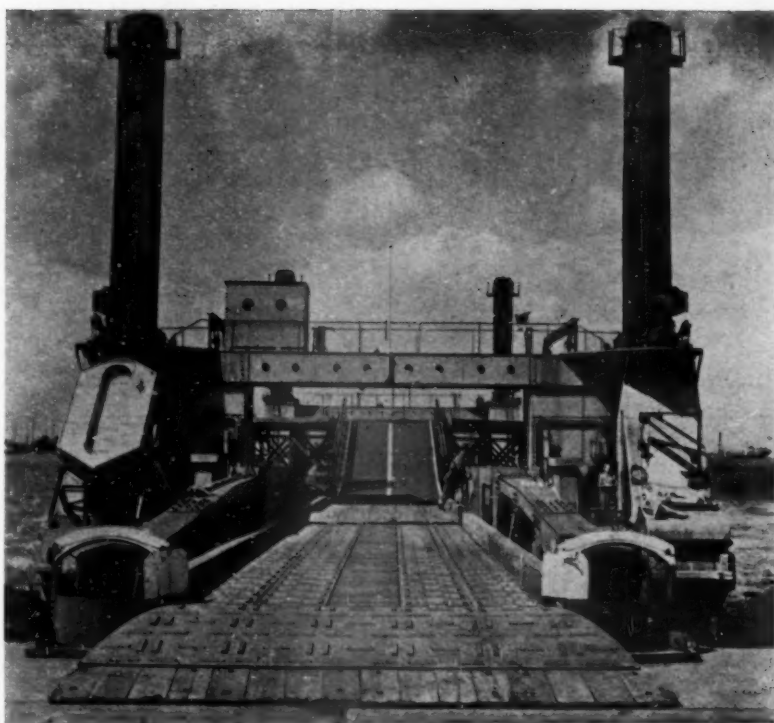


Fig. 2.—Illustrating a telescopic bridge span used for connecting unloading platforms of the L.S.T. Pier-heads.

finished a few hours ahead of schedule. An immense amount of work had to be done to make good deficiencies and to carry out amendments in design.

The "Whales" were building in Wales, on the East Coast and the West Coast of Scotland, and had to be towed by the Navy round to Southampton. One or two of them were already on the way when Dorman Long were asked to take over co-ordination of the work. The vessels were 150 feet long by 60 feet wide, and in addition to certain work remaining to be done on all of them, some had to receive special treatment. On each of the latter 30 tons of steel brackets had to be ranged along the sides from which 300 tons of concrete blocks were hung as additional protection. This type of vessel also required overhead ramp structures involving 30 tons of structural steelwork. Other vessels needed the addition of large attachments to take buffer pontoons.

Until the vessels arrived it was not known how much work each required and some of them, in addition to deficiencies, sustained damage during the long tow, and this also had to be rectified. On one vessel alone nearly two miles of welding was done on arrival at Southampton. The work went on day and night without interruption. Fortunately, the weather was favourable and 15 vessels were ready for service a few hours earlier than the due date.

In addition, this company undertook a great amount of steel fabrication in connection with the harbours. Spud columns, 90 feet long, floating ramps and Rhino pontoons were also included in the Company's activities. One of the largest constructional shops at the Middlesbrough works was laid out and equipped for rapid mass



Fig. 3.—Showing "Whales" connected and some of the first traffic off one of the completed piers.

production of highly specialised floating bridge work, and for six months, day and night, shifts and week-end working were operated.

The Company's Clarence By-Products plant also made a particularly valuable contribution to the war effort. Dorman Long were one of the leading producers of anthracene for the manufacture of khaki dyes and toluene for explosives, and benzene for essential war purposes.

The first difficulty experienced by Guest Keen Baldwins Iron and Steel Co. Ltd., due to war conditions, was the cessation of supplies of foreign ore, on which the production policy of the blast furnace plants was based. This called for the immediate installation of additional plant at the Company's ore workings in Oxfordshire, sufficient to increase the output by 100%. The problem of conveying regularly every week 20,000 tons of ore this distance, and of discharging it and giving a quick return of the empties at blast furnace plants on the dockside (laid out for handling imported foreign ore), under conditions of black-out and air-raid alerts, was no small one.

When on a foreign ore burden, approximately 65 cwt., of material were charged in the blast furnaces to make 20 cwt. of pig iron. With a burden consisting almost entirely of home ore as much as 110 cwt. were required. So, although output of pig iron was down, the quantity of material charged increased by 25%, compared with 1939. This meant that up to 29 cwt. of slag had to be disposed of for every ton of iron made. Naturally this slag could not be tipped during black-out hours, and immense difficulties had to be surmounted in storing and screening this slag in ladles during the long winter nights, and then tipping the accumulation and the current make during the short days.

Another grave problem was that of ventilation at the blast furnaces and steel melting shops, consequent on

the complete screening of glare. Apart from the normal fumes given off when tapping a blast furnace, the iron from the home ore burden was too high in sulphur for the melting shops and had to be de-sulphurised by the addition of soda ash, which further accentuated the fume problem.

The difficulties at the steel melting shops were those of anti-glare screening, trying to hold furnaces just ready for tapping for many hours during air-raids on neighbouring towns, and the call for a long range of special steels to rigid specifications to be made from raw materials which could hardly be classed as

ideal when compared with pre-war standards.

The mills, in addition to rolling 3,645,000 tons of ingots from the Company's melting shops, during the years 1940-44, have dealt with more than 400,000 tons of ingots from outside sources, chiefly from the U.S.A.

One of the first urgent war demands was for air raid shelters, designed by the Company, based on the steel supports supplied by them for underground roadways, and in a very short time sufficient shelter accommodation for three-quarters of a million people had been provided. In the air raid shelter line, there then followed the demands for large quantities of sheets and fittings for the Anderson and Morrison shelters.

One of the first munition products made was in square billet form for aerial bombs. Large tonnages of round bars for the French 75 mm. shells were produced until France fell. Then followed large quantities of square billets for forging and round bars for machining into shells ranging from 25 pdr. to 7.2 in.

Simultaneously this company was called upon to produce alloy steel armour plates for tanks, and a heat-treating department was set up to quench, temper and flatten the plates for subsequent shaping and welding into the tank structure.

The requirements of the shipbuilders absorbed large tonnages of plates and sections in many different qualities for all types of ships, submarines, invasion barges and "Whales." Sections for Bailey Bridges were also supplied in very large tonnages, as also were special steels for aircraft bolts, nuts, etc.

While these many-sided activities were in full flow, every effort was made to maintain the efficiency of the plant, as is evidenced by the fact that during the war years a new battery of coke ovens was brought into commission, two blast furnaces re-built and a gas cleaning plant installed, to mention but a few items.

The change from peace to war-time conditions so far as the usual products of Stewarts and Lloyds are concerned was like diverting a full and fast flowing river from its ordinary bed to a rapidly constructed war-time channel. Although this company's manufactures were essential both in peace and war the switch-over was not a simple operation, especially when it became evident that the flow of production would develop into a spate.

With the co-operation of executives and employees, the results of the war effort, so far as they are able to be told, can be modestly given as a remarkable achievement. The Admiralty, the Army and the Air Force requirements, direct and indirect, made it necessary to adapt tubes for war purposes, with the result that quantities formerly spoken of in thousands of feet were referred to latterly in thousands of miles. For example, for boom defences, over 15,000 miles of tubes have been supplied, for fire fighting mains over 1,000 miles, for the Oil Grid in Britain over 1,200 miles and for the British Army overseas, over 4,000 miles. These figures do not include the quantities used in the two schemes which have recently been made known to the public, viz., Operation "Pluto" and Operation "Fido."

Oil companies, shipbuilders, locomotive manufacturers, amongst others, have also been supplied with many thousands of tons. Tubes have been used extensively in the production of the most modern types of projectiles, shells, bombs, other munitions and projectors. Over 10 million tubular units to particular design and specification have been supplied for these purposes, representing over 150,000 tons of tubes.

Many thousands of miles have been supplied and used for almost every conceivable type of constructional purpose. An interesting feature has been the design and erecting of tubular hangers and hides for aeroplanes and bomber maintenance platforms, and tubular roofs for temporary houses, for which large orders are at present being executed.

Shell forgings within the full range of sizes required by the Army were also produced by the Company and up to December, 1944, reached a total of 50 million, for which over one million tons of steel were used. Other weapons of war of various types supplied amounted to 14 million pieces.

From September, 1939, to the end of 1944, the output of Stewarts and Lloyds amounted to: Pig iron, 7,500,000 tons; steel ingots of all qualities, 4,500,000 tons; steel tubes, fittings, and specials, 2,500,000 tons,

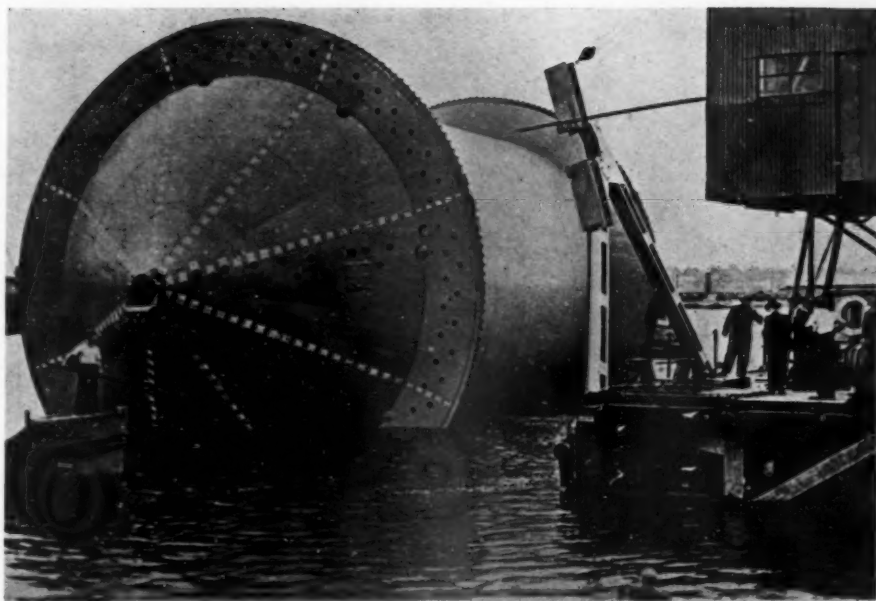


Fig. 4.—A "Conun" (H.M.S. Conundrum) being moved into position for winding on steel pipe for operation "Pluto" (pipe-lines under the ocean).

and these figures do not include the valuable contributions made by their Subsidiary Companies in this country and in South Africa and Australia.

The first effect of the war was also to intensify the demand for practically all the normal products of The United Steel Companies. Pig iron, sections, and particularly plates, were required in enormous quantities from the Appleby-Frodingham plant in North Lincolnshire, owing especially to the expansion of shipbuilding and ship repairs. In spite of these demands, and the consequent expansion of plate-rolling capacity, however, Appleby-Frodingham also undertook some quite novel tasks, including the heat-treatment of armour plate and the production of all the component parts of tank landing craft.

Maximum outputs were also required from the continuous billet, bar and strip mills and the forging plant of Steel, Peech and Tozer and United Strip and Bar Mills, on the Sheffield-Rotherham boundary. In these cases, however, there was some change in the nature of the products, particularly a partial diversion to shell steel in the case of the rolling mills and to gun forgings in the case of the forging plant; whilst three entirely new shops were put down for the machining of gun forgings. Shell steel sufficient for over 600 million shells was produced; whilst the output of passed test gun components in 1942 was the largest of any forging firm in the country.

The neighbouring branch of Samuel Fox and Company, at Stocksbridge, some 10 miles north-west of Sheffield, was concentrating increasingly before the war on the production of alloy and special steels and of highly finished products such as springs and cold-rolled strip. Here again, the main effect of the war was to intensify the demand for these products—for instance, for stainless steel for aircraft exhaust pipes.

Equally, there could be no change in the basic product, coal, of the Rother Vale Collieries, on the eastern

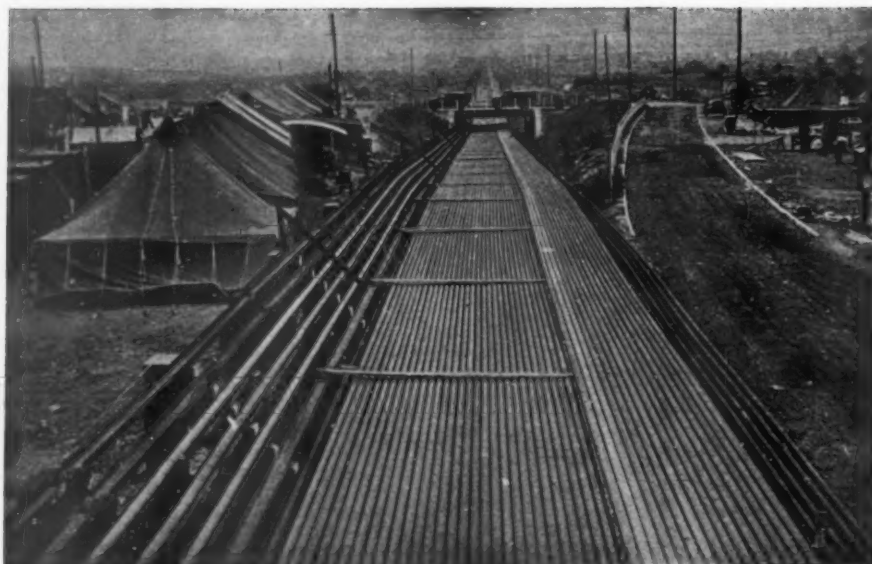


Fig. 5.—“Hamel” pipe ready for winding on the “Conun.” Stored in three-quarter mile lengths, some 200 miles of piping is shown.

outskirts of Sheffield, or of the products of carbonisation—coke, gas, sulphate of ammonia, tar and benzole. Nevertheless, there was considerable development of the products of the tar and benzole distillation plants.

The one branch which was appreciably diverted from its normal forms of production was the Workington Iron and Steel Company, in Cumberland. Here, as at Rother Vale, the demand for coal and coal derivatives was fully maintained. On the iron and steelmaking side, however, owing to the shortage of hematite ore, half the supply of which is normally imported, and to the possibility of curtailing consumption of the branch's main finished product, rails, a considerable part of the personnel was diverted to special war-time activities for which the remote location of the works made it particularly suitable.

Workington was, in fact, the site for many of the Agency Factories, whose operation represented the United Steel Companies' second main contribution to the war effort. The outstanding example was the Distington Hematite Iron Company, an entirely new electric steelmaking plant was constructed with seven 20-ton electric arc furnaces, representing a very considerable proportion of the country's total output of electric steel. Workington was also the site of no less than seven other plants operated on behalf of the Government, these activities including shell forging and machining, the assembly of jeeps and lorries in preparation for D-Day and the salvage and repair of aeroplane engines.

Apart from Distington, The United Steel Companies operated several other major Agency Factories, notably the steel-works and rolling mills of the Barrow Hematite Steel Company, and the steel-works and forging plant of the Monk Bridge Iron and Steel Company, of Leeds, after their acquisition by the Ministry of Supply. In both these cases the accumulation of deferred repairs and the delays in obtaining the new equipment authorised by the Ministry made the attainment of the

target levels of output a very formidable task.

This, then, was the war effort accomplished by The United Steel Companies—record outputs of normal products such as plates and alloy steel, and of abnormal products produced from the existing plant such as shell steel and gun forgings, together with the operation and in some cases also the construction on behalf of the Government of no fewer than 14 separate works, whose activities ranged from electric steelmaking to the assembly of jeeps.

One final point must be emphasised. The main stimulus to the mechanical improvements and consequent lowering of costs

achieved was provided not by a desire for increased profits, which were in any case severely limited by the operation of the Steel Prices Fund, but by the fact that the national interest called for the most economical use of the strictly limited labour force available.

When assessing the contributions of various plants in the industry, it should be remembered that all contributed substantial numbers of their peace time labour force to the Services. One firm in particular has over 5,000 of its employees in the Services and these have had to be replaced by older men and female labour. The success achieved has been largely due to the fact that the industry has acted nationally during the war period and it should continue to do so. It is recognised that much money will be needed to rehabilitate the industry and this money should not be spent in a haphazard manner. With this object in view, the Federation have appointed from within the industry a committee which has been asked to review all schemes of extension or expansion. They have been authorised to employ independent technical experts and it is hoped by this means that the efficiency of the industry will be increased and carried out in an orderly manner, having the national needs as the great objective.

READERS who are seeking information on diamonds as a cutting medium for metals and non-metallic materials and on the truing of grinding wheels will have their search greatly simplified with the aid of two bibliographies recently published. That on diamond cutting indicates the literature on the subject from 1900 onwards, while the bibliography covers the important literature on the truing of grinding wheels published since 1922.

Copies can be obtained on application to Diamond Research Department, Diamond Trading Co. Ltd., St. Andrew's House, Holborn Viaduct, London, E.C.1.

The Blast Furnace Burden

By Theodore Powell

The economical production of good quality steel depends to a large extent on the production of suitable irons from the blast furnace and, while many factors in the furnace operation influence the economical production of suitable irons, the burdening of the furnace probably has the most important influence. The blast furnace determines the character and quality of the pig iron produced, thus it has a direct influence on the costs incurred in producing steel. In this article the author discusses the subject in relation to steelworks requirements, pre-war and wartime blast furnace burdens, the ideal burden, and, since coke constitutes approximately 50 per cent. of the burden, particular attention is directed to cokes. It is believed that criticism of the British iron and steel industry, by people outside the industry, would be more constructive if they had some knowledge of various aspects of this subject and this somewhat brief outline is intended to clarify the position regarding British blast furnace practice.

THE process of manufacture of pig-iron is complex and is the result of continuous change with the object of increasing production and decreasing the cost. Although many changes have been made in the methods employed, the fundamental principles remain unchanged. Among the contributions to increased and more economical production are increased size of blast furnace and greater purity of the materials charged by which suitable iron can be supplied to the melting shops at the steel works with great regularity. The uniformity in supply of suitable iron is a major factor in the production of good steel and to produce such iron the blast furnace burden must be uniform and the plant worked on a regular basis. During the war British steelmakers, in the majority of instances, have not had suitable irons; variations in silicon and sulphur were the most objectionable features, since the phosphorus content was constant for a particular practice, and these were caused by the drastic wartime alterations to the blast furnace burdens.

Pre-war Burdens

Before the war the blast furnaces in this country making iron for conversion into steel could be roughly divided into three classes, namely:—

1. Those operating on home ores.
2. Those operating on a mixture of home and foreign ores.
3. Those few operating on foreign ores.

The predominating practice was to use mixtures of home and foreign ores. Operators using foreign ores had been able to determine by practice over many years the ores most suitable to their requirements and which gave the best results when mixed with the particular grade or grades of home ore available.

In making iron for steelworks use it is necessary that it should have low silicon and sulphur contents and the composition should fluctuate as little as possible. This can be effected successfully by careful control of the materials used in the furnace, especially with regard to chemical analysis and physical properties. It must be appreciated, however, that conditions in Britain are much more difficult than in the United States. In the latter country high grade ores are available with an average iron content of 50 per cent or more. Further, the ore from the main ore regions is carefully graded and materials of varied composition are mixed in order to give a close approximation to a predetermined value.

Thus, the characteristics of a particular ore are known and the blast furnace manager can rely on a continuity of supply of ore having the same characteristics. In Britain, however, the bulk of the ore mined is of low grade and has an average iron content of less than 30 per cent. Indeed, a considerable quantity of ore is now being used in which the average iron content is nearer 20 per cent. Apart from the low iron content of the ore, however, not only does the quality vary considerably in different mines, but there are often important differences in the principal constituents of the ore from the same mine. Thus, the maintenance of efficient control by grading has always been a problem in this country and the difficulty is increased the greater the proportion of home to foreign ores.

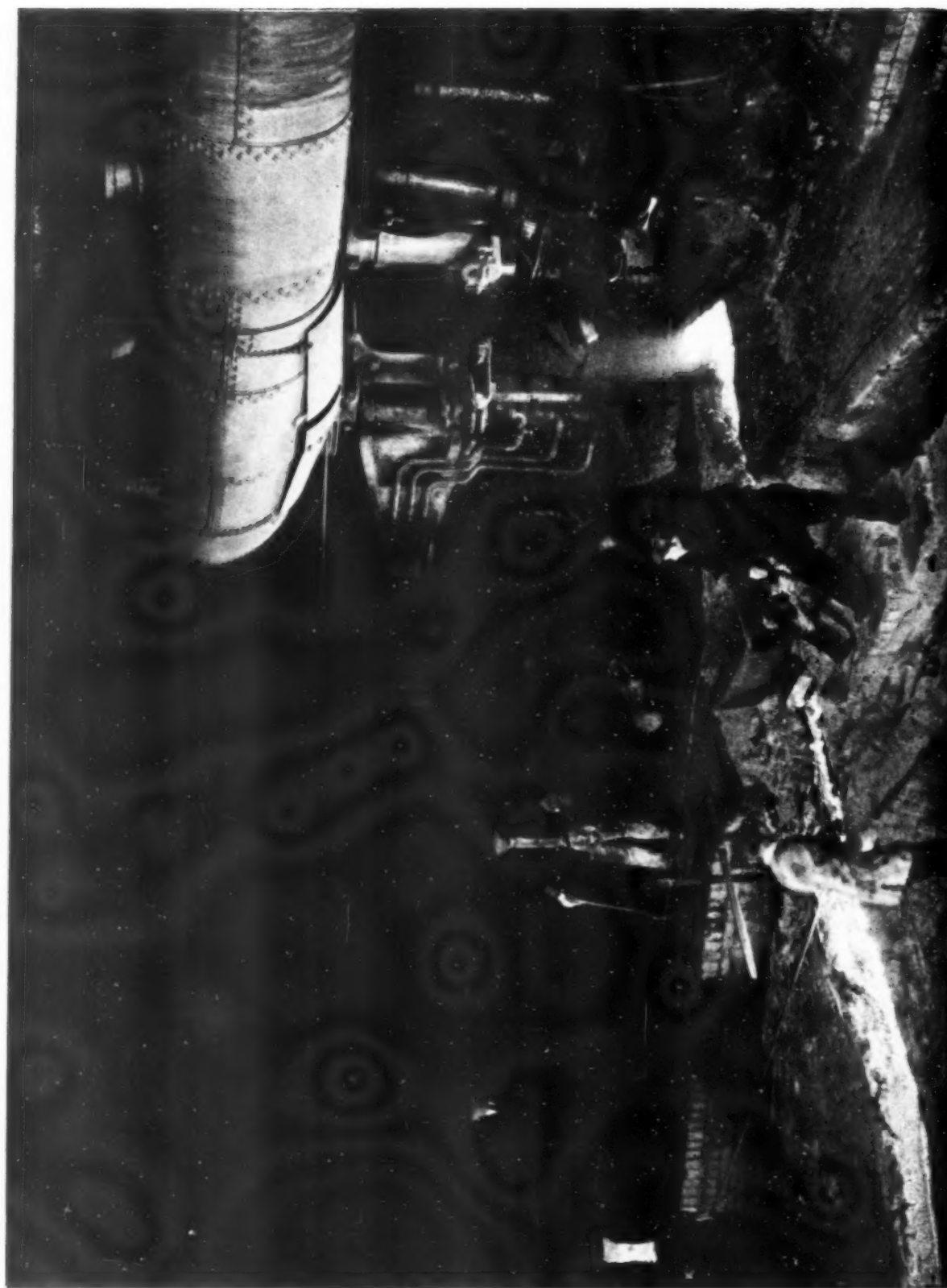
War Burdens

As the war advanced so the amount of rich foreign ores arriving in this country diminished. Quantities used in the pre-war burdens dwindled almost to vanishing point, these were substituted by low grade Midland ores and thus the war-burdens were impoverished. The greater use of Midland ore introduced another factor affecting the economical operation of the plant. A wider application of mechanical diggers to meet the demand caused wide variations in the size of the ore loaded in the bunkers. In some instances, huge lumps appeared in the furnace bunkers; they frequently gave cause for wonder how they passed through a wagon door. Some lumps were so large that a crane had to be used to remove them so that they could be broken with wedges on a dump. Lumps that do get into the bunkers cause considerable trouble in getting them out of the bunker eyes.

Some indication of the variation in size of calcined ore loaded by mechanical diggers is shown by the following example from practice: The calcined ore contained some very large pieces of scar and half-raw stone with a large amount of fines. The sizing test, carried out after the large pieces were removed, gave:—

19.1% on $1\frac{1}{2}$ in. .
9.8% on 1 in. .
15.8% on $\frac{1}{2}$ in. .
19.9% on $\frac{1}{4}$ in. .
16.6% on $\frac{1}{16}$ in. .
18.8% through $\frac{1}{16}$ in.

The silica content of the material on the $1\frac{1}{2}$ in. was 16.8% and increased until the material below $\frac{1}{16}$ in.



s
c
fu
p
in
p
ti
bi
pe
w
co
ca
fu
la
on
Ve
su
er
fi
ex
lar
the
"a
of
any
by
bur
ma
into
is
trou
slag
wor
unk
In
furn
app
ava
com
calc
and
Nor
cust
coke
of th
incr
ratic
cons
form
slag.
the c
Exce
of th
the c
provi
the v
charg
only
atten
result
tions
avai
tem h
icular

showed a content of 32.96%. Samples taken from a consignment of 250 tons of so-called calcined ore showed further losses of 1.8, 1.9, 16.8, 24.6 and 26% respectively.

Obviously the use of such low grade ores greatly increases the slag volume and coke consumption: in practice slag volumes were doubled and coke consumption increased by, say, approximately 50% of pre-war blast furnace operations. In addition there was also the period of slack blast during air raid warnings, during which the furnace stock lines were not maintained and, consequently, the distribution of the burden was upset causing various troubles, frequently necessitating extra fuel consumption. In an endeavour to even out irregularities of sizes of materials, the use of the McKee top on mechanically charged furnaces was found invaluable. Various charging sequences were tried until the most suitable one could be found. To compensate for the erratic deliveries of ores burdens were changed four and five times in a week. Even so some trying times were experienced by blast furnace operators and only by the large slag volumes made and by the careful watching of the furnaces was serious trouble prevented, for example, "a lime gob."

The melting point of limestone is in the neighbourhood of 2,500° C., a temperature which is much higher than any attained in the hearth of the blast furnace, and only by intimate contact with other constituents of the burden having lower points of fusion can it combine to make a free-running slag. If an excess of lime comes into the hearth it cannot be taken up in the slag and so is retained in the hearth. This causes very serious trouble if the excess is large. Difficulty in running the slag off the furnace, shoddy at casting time and even worse trouble can be the result of this excess lime due to unknown chemical changes in the ores charged.

It should be remembered that, in making up the blast furnace burden, the furnaceman first decides the approximate proportions it is desirable to use the ores available, from which he can determine the average composition of ore mixture in each charge and to calculate the amount of ore to produce one ton of iron and, at the same time, the weight of impurities. Normally, with ores averaging, say, 50% iron, it is customary to operate on a ratio of less than one ton of coke to one ton of iron produced, but as the iron content of the charge is reduced the charge of coke must be increased and with the very lean home ores the normal ratio is far exceeded in order to remove the remaining constituents of the charge. The impurities are in the form of acids and bases, and these combine to produce slag. The combination of acid to base likely to produce the quality of iron desired is determined by experience. Excess acid must be fluxed with limestone. An analysis of the limestone determines the available base enabling the calculation of stone to flux with the excess acids to provide the required ratio. For good furnace practice the volume of slag must be controlled, but when the charges are frequently changed only experience and careful attention will give satisfactory results from different combinations of materials that may be available. Even when the problem has been solved for a particular furnace, it is not likely

that the same results will be obtained from another furnace using the same materials.

Function of the Blast Furnace

Consider now the function of a blast furnace which is to reduce metallic iron from its oxides. The reducing agent is provided by the fuel used (coke), or more correctly by the carbon of the coke less carbon dissolved by the pig iron and that in the flue dust carried out by the gases. The carbon reaching the tuyeres is gasified by the oxygen of the blast producing heat and the reducing gas carbon monoxide via carbon dioxide. Some ore is reduced by solid carbon and some carbon reacts with carbon dioxide in the shaft of the furnace.

Reduction of the oxides by carbon monoxide is indirect reduction and exothermic. Reduction by carbon is direct reduction and endothermic. Gruner's ideal working was that all carbon burnt in the furnace should reach the tuyeres and be oxidised there to CO and all reduction of oxides above the tuyeres should be effected by this CO with CO₂ as a stable product of interaction. Clements has investigated three cases and concluded that Gruner's ideal should be restated as follows:—

In all cases for a given set of conditions, maximum fuel economy will be attained when the maximum use for reduction purposes is made of CO generated at the tuyeres.

It follows that the most intimate contact must be obtained between ore and the ascending gases, so that the ore is reduced before reaching the region in the furnace where the temperature is high enough to allow the carbon of the coke to react with the CO₂ formed by the reduction of the ore to form CO. Large pieces of ore will only be reduced on the outside by the ascending CO gas, leaving the greater portion to be reduced by solid carbon which means a higher consumption of coke if nothing else.

Ores should be permeable to the gas. Dense ores, not being permeable to the gas, act more or less in a similar manner to large pieces of ore. They come down into the hearth of the furnace unreduced and have to be reduced by solid carbon. Many operators could tell of pieces of dense ore being taken from a tuyere housing, when changing a tuyere, that looked as though they had not been in the furnace at all! Too much dense ore in a burden causes, besides higher coke consumption, hearth troubles, such as cold slag, which is very difficult to run off the furnace, and shoddy iron.

Temperature is essential to all blast furnace reactions and this can only be provided in the shaft of the furnace by absorption of heat from the ascending gases. This again stresses the importance of good gas/solid contact in the shaft of a blast furnace, which is realised by everyone in the blast furnace world.

A very interesting and useful report was issued some years ago by the United States Bureau of Mines on the importance of gas/solid contact. In the experimental work from which the report was prepared a furnace was worked for a period of nine months on ore graded for silica content only. The second period of eleven months two sizes of ores were used—coarse and fine. All the coarse ore passed a 3 in. screen and 89% remained on a ¾ in. screen. All the fine

The facing illustration shows the process of tapping one of the largest blast furnaces operating in Britain. It has a capacity of 700 tons per day and is installed at the Dagenham Works of Ford Motor Co., Ltd. (We are indebted to Ford Motor Company for the use of colour printing plates and for permission to reproduce this fine illustration.—Editor.)

ore passed a 1 in. screen and 90% remained on 40 mesh. The ore was charged by the layer method, the first charge containing all fine ore and the second all coarse and so on. The third period of sixteen months, three sizes of ore were used—coarse, medium and fine. Twice as much fine ore as coarse ore was available, so that the order of charging was:—coarse, fine, medium, fine, coarse, fine, medium, fine. The coarse ore passed a 3 in. screen, and 95% remained on a 1 in. screen. All the medium ore passed a 1½ in. screen and 79% remained on a ¾ in. screen. The fine ore passed a ¾ in. screen. Each charge contained only one size of ore with the necessary coke and limestone. The limestone used was normal in composition.

During the above periods it was stated that the coke and limestone remained practically the same in physical size and chemical character and that each reduction in ore size was accompanied by an increase in CO₂ content of the top gas and by a decrease in coke consumption. The second period showed a decrease in coke consumption of 3 cwt. and an increase in output per week of 434 tons over the first period. The third period showed a decrease in coke consumption of nearly 3·9 cwt. and an increase in output per week of 574 tons over the first period.

The average CO : CO₂ ratio in the top gases of the first period was 2·68, of the second period 2·20, and of the third period 1·54. This last period was the average of 74 gas samples.

Coke consumptions:—

1st Period ..	21·97 cwt.
2nd Period ..	18·94 cwt.
3rd Period ..	18·07 cwt.

Ideal Burden

What would be an ideal burden? The keynote of blast furnace practice is smooth and regular working. To achieve this the ores must be of such size as to:—

1. be permeable to the ascending gases so as to absorb heat for the necessary chemical reactions to take place at the right place.
2. allow an even flow of gases over any cross sectional area.

The limestone must be crushed small enough to combine easily with other slag-forming constituents of the burden—it has previously been stated that the melting point of lime is not attained in a blast furnace—and properly screened because the fines contain siliceous matter from adhering clay. A self-fluxing burden would be an advantage if sufficient slag were made to carry the sulphur.

The coke must resist any tendency to premature combustion by the ascending gases and should retain its original form until close to the tuyeres where it must be of such porosity as to burn at a rate to meet the desired output of iron.

The ideal burden would be that all materials charged to a blast furnace, fulfilling the above-stated requirements, be in spherical form of equal size. Of course, all materials in spherical form is not practicable, but how near to the ideal can a burden be made?

Future Burdens

The more intimate contact the slag forming constituents of the burden make, the smoother the operations of formation and melting. All ores should be crushed to the desired size and screened. The fines should be sintered before charging to the furnaces. Each

particular ore size—there will probably be two or three—should be mixed on the stocking ground to give a certain chemical analysis. It will then be transported to the furnace bunkers in sizes and charged in sizes, that is, layer charging. The furnace charge will be the calculated weight of a particular size of ore with the necessary flux and coke.

A great amount of research work has been and is being carried out on the sintering of fine ores. The sinter has to be reduced in the blast furnace, as with the other ores used, therefore, it should not be glazed, but be porous, dust free, strong and of a size conforming with the remainder of the burden.

Coke

Chemically, coke will be as low in ash and sulphur as the coals used allow. The blast furnace operator requires to have these with as little variation as possible. Both the ash and the sulphur have to be fluxed, consequently an increase in one or both means more slag which requires carbon to form and melt it with a decrease in the available carbon.

The more available carbon in coke the lower the coke consumption. Furnace performance is judged on coke consumption but it is not right to compare performances on this as one operator may have a high ash and sulphur coke while the one with whom the comparison is made has a lower ash and sulphur coke. Comparisons, other things being equal, should be made on available carbon in the coke.

Sulphur in coke is the principal source of sulphur in the blast furnace burden and therefore should be as low as possible. The higher the sulphur the more basic the slag will have to be, carrying a higher formation temperature and the larger the volume of slag to carry it. All of which means extra coke consumed. Until adjustments have been made excess sulphur will pass into the iron.

To obtain a regular suitable iron the relationship between hearth temperature, slag analysis and slag volume must be maintained. It is imperative for the desired result. A temporary increase in blast temperature often corrects a disturbance of this balance in the hearth. This should not be of long duration, because a furnace is worked with a blast temperature suitable for regular driving and if it is necessary to increase this temperature for a lengthy period, the driving of the furnace becomes irregular. It has often happened that a furnace driving well on a blast temperature of 550 to 600° C. has slackened in driving after an increase to 650–700° C. for four hours.

The variations in the ash content mean variations in slag volumes which upset hearth conditions as explained above. Coke should preferably be dry, if this is not possible the moisture should be as low and constant as possible.

What should the physical properties of coke be to ensure the regular working of furnaces so necessary to produce good results?

It is important to bear in mind that practically no solids other than coke should be present from hearth level to a short distance below the bosh line, all the other constituents of the charge having been converted either into liquid or gas. The tuyeres are spaced equally round the furnace with the centre lines converging on the centre of the hearth. It is hoped by this arrangement to obtain the best penetration and the most uniform distribution of blast over the whole of this area.

Under the most favourable conditions, this is practically impossible of attainment owing to the drop in velocity as the centre of the hearth is approached. Also the coke at the tuyeres is burnt to such a size that a point is reached where the resistance of the small pieces of coke to the blast stream is overcome and they are forced through the interstices of the larger coke and take up a position nearer the centre of the hearth.

To obtain the good results which are hoped for, it is essential that the velocity of the gas shall be as near uniform as possible over the whole area of the hearth. It is only hoped to approximate this condition by using a uniform coke. It follows, therefore, that if the coke charged contains an excess of breeze or is so badly fractured and fingered that it will disintegrate in its passage through the furnace, the tendency will be for the smaller coke to take up a position nearer the centre of the hearth with an annulus of the larger coke. This would be in addition to the amount of smalls made at the tuyeres previously mentioned and would increase the volume of the centre cone.

It has already been shown that even with uniform coke, owing to the drop in velocity as the centre of the hearth is approached, it is practically impossible to obtain a uniform flow of gas over the whole cross-sectional area. How much more difficult must it be, therefore, when the percentage of voids has been enormously reduced in the centre of the furnace.

Excessive small coke reducing the annulus causes tuyeres to be burnt and may contribute to hearth breakouts. The writer has seen, not once but many

times, a huge pile of small coke put out through the tapping hole near the end of a cast. This has had to be shovelled away before the gun could be used to stop the tapping hole. A ten-ton slag ladle has been filled with this small coke from one cast. If the furnace had had a succession of burnt tuyeres the removal of this small coke from the furnace resulted in a cessation of tuyere failures for at least twenty-four hours.

Summarising the requirements, coke should be low in ash, sulphur, moisture and be of uniform size, free from breeze. It should have a matt fracture and be strong and finely porous. The porosity about 50% with a low bulk density. It must resist premature combustion and retain its original form until close to the tuyeres.

The coke oven manager has his difficulties with variations in coals used, but a great deal can be accomplished towards obtaining the most suitable coke for the blast furnace by experiment and close co-operation between the two plants.

Finally, assuming that the blast furnace plant is designed in the best possible way, incorporating every device known to give the most efficient operation, then it is essential to have delivered to it a supply of suitable material both chemically and physically in order to obtain the best results. In other words the benefit of good plant design can be lost by the supply of unsuitable raw materials. The conditions for the greater part of the war period have not been normal, materials have had to be used which, under normal conditions, are regarded as unsuitable for working the blast furnace in the best possible manner.

Special War Equipment—"Shark"

DETAILS have just been released of special equipment prepared to ensure the speedy rehabilitation of coastal ports, which, it was anticipated the enemy would destroy as the Allies advanced from Normandy. The basis of the scheme, known as "Shark," was the construction of floating steel caissons in units which could be transported to the Continent and used to seal rapidly locks and dock entrances wrecked by demolitions.

The work was undertaken by Dorman Long and comprised 151 large, and a similar number of small, units, complete with necessary timber flaps, sills and accessories, involving 10,000 tons of structural steel, 3,000 tons of timber and a vast amount of ancillary equipment. The assistance of 15 structural steelwork firms and 3 civil contractors were sought to get the work completed in the time available.

The floating steel caissons were composed of units, each 30 ft. in height by 7 ft. in width and 40 ft. in length. By bolting a number of these together the greater part of a damaged dock entrance could be closed whilst the openings between the caisson sides and the dock entrance walls would be closed by heavy timber flaps, reinforced with steel, and hinged on the outer units, the pressure of the impounded water retaining these flaps against the walls. The use of timber permitted the swinging ends of these flaps being readily cut at site to conform to a particular dock wall face.

It transpired that the enemy was unable to effect destruction on the anticipated scale, which enabled the S.H.A.E.F. greatly to amend their original requirement and production was terminated after approximately one-third had been made.

Air Clutches

DESCRIPTIVE information relative to air clutches is given in two recently published brochures. Each deals with a distinct design, but both are designed under the Fawick patents. One will be known as "Crofts Airflex Clutch," and the other as "Crofts Air Ring Clutch." Both types embrace either the internal expanding or outside constricting designs, the type to instal depending upon the class of drive.

The great advantage of the Airflex Clutch is that, in addition to functioning as a clutch, it is flexible in all directions, so that it incorporates all the advantages of a flexible coupling, also it is self-contained; there are no loose parts or wearing surfaces except the friction linings, which are replaceable.

The Air Ring Clutch functions in a similar manner to the Airflex Clutch, but its design is entirely different in so far as the friction linings or blocks are not attached to the air bag, the use of the latter being simply to operate the clutch. The drive is taken from the friction blocks through torque bars to the clutch body.

One of the greatest advantages of these clutches is the simplicity of operation, which can be either local or remote. The largest sizes can be put in and out of gear by finger tip pressure on a small lever, by the turning of a taplike valve or alternatively by the pressing of a button type valve, they can also be operated electrically. Compressed air is the means of operation and the clutches can be operated from either an existing compressed air pipe line or combined air compressor and receiver can be installed.

For further information readers are advised to obtain copies of the three brochures from Crofts (Engineers) Ltd., Thornbury, Bradford.

High Tensile Steel for Castings*

By W. West, C. C. Hodgson and H. O. Waring

A number of aspects of steel making and foundry practice, investigated by the authors during the last five years in connection with the production of medium and high-tensile steel castings, are co-ordinated in a recent paper presented to the Lancashire Branch of the Institute of British Foundrymen. The types of steels were of the low- and medium-alloy varieties capable of giving ultimate tensile strengths from 35-65 tons/sq. in. on sections up to 4 in., or as high as 75 tons/sq. in. on smaller sections, accompanied by good ductility and resistance to impact.

Relationship Between Type of Primary Structure and Mechanical Properties

The kind of primary crystals and the way in which they are arranged varies according to metal temperature, method of running, shape of casting, and other variables; this has been well illustrated in a recent paper by Gray.⁹ Considering test blocks, for example, depending on the casting conditions a variety of structures can be obtained from completely columnar-dendritic (Fig. 7) to almost entirely small equi-axed crystals (Fig. 8), or an intermediate type (Fig. 9).

The influence of primary crystal type on mechanical properties seems to vary with the kind of steel and the heat-treatment it has received. The more highly alloyed the steel, or the harder its condition, the greater seems to be the tendency for marked columnar crystals to reduce both the ductility and the Izod value, at least when the direction of maximum growth lies at right angles to the axis of the test piece. This is an opinion based on the examination of a large number of tensile and Izod fractures, and not a statement made after

TABLE IV.
RELATIONSHIP BETWEEN PRIMARY CRYSTAL STRUCTURE AND MECHANICAL PROPERTIES.

Preliminary Treatment:—Normalised 900°C., and Softened 640°C.
Specimens 1 in. thick cut from centre of block for macro (see Fig. 11).
Final Treatment of remaining parts of Test Block:—Normalised 850/860°C.
Tempered 600 610°C. Water Quenched.

Chemical Composition						Macro Structure	Mechanical Properties			
C	Si	Mn	Ni	Cr	Mo		Y.P. t.s.i.	U.T.S. t.s.i.	E. %	Izod, ft. lb.
0.23	0.32	1.38	0.65	0.09	0.32	Columnar				44, 45
						Equi-axed	29.4	42.4	21	44, 41
0.26	0.43	1.53	0.87	0.12	0.33	Columnar				41, 39
						Equi-axed	36.0	51.2	17	51, 31
0.26	0.45	1.37	0.96	0.17	0.32	Columnar				36, 35
						Equi-axed	38.8	49.0	17	55, 25
0.24	0.30	1.46	0.85	0.15	0.31	Columnar				30, 29
						Equi-axed	34.5	45.5	20	38, 40
0.25	0.42	0.153	0.85	0.16	0.33	Columnar				38, 39
						Equi-axed	40.4	52.0	16	36, 31

considering the results of a full investigation into the problem.

Fig. 7.—Columnar dendritic structure.



Fig. 8.—Structure almost completely small equi-axed crystals.



Fig. 9.—Structure of an intermediate type.



An investigation of the influence of primary crystallisation on the Izod value has been made on manganese-molybdenum steel used in the normalised and tempered condition. The test block shown in Fig. 6 cast open top in oil sand moulds was used, or a slightly modified pattern, similar in general dimensions. From amongst a considerable number of tests a few selected from some of the test blocks of intermediate type (Fig. 9) are given in Table IV. The specimens were prepared

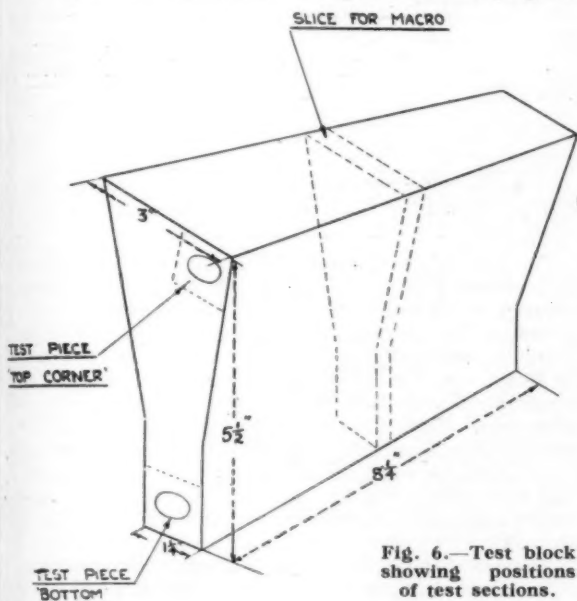


Fig. 6.—Test block showing positions of test sections.

as shown in Fig. 6; it will be seen, if this illustration is considered in conjunction with Fig. 8, that specimens from the bottom of the block had a small, equi-axed structure whilst those from the top of the block had a pronounced dendritic structure. It is considered that the results obtained establish that for this kind of steel, used in the condition stated, there is no evidence that marked columnar primary crystals have any important influence on the Izod value.

Heat-Treatment

There are only two main essentials for satisfactory heat treatment of steel; firstly, the means of heating the article uniformly to the required temperature without excessive scaling or decarburisation and secondly, the ability to cool the heated article at the required rate.

To say that a furnace capable of producing a uniform temperature throughout the charge (or, in the case of a continuous furnace, in the article to be treated) is a first essential towards satisfactory heat treatment may sound like repeating a trite truism, but it cannot be too strongly emphasised that many of the older, large, batch-type, annealing furnaces are not suitable for quenching and tempering operations unless they are filled in a manner which is entirely uneconomical. In practice the last mentioned proviso is hardly ever met, rather the reverse, for such furnaces are often pressed into service when heat-treatment capacity is short and when, consequently, the temptation to overload them is great. A continuous furnace is the ideal piece of equipment for heating castings of the weight and size we are discussing, because

by this means the second of our two postulated essentials is most readily met, but this does not mean that quite satisfactory normalising or hardening cannot be done from batch type furnaces, it can, provided the furnace is charged in such a way that uniform heating is possible and, perhaps this is more important still, the circulation of the cooling medium (whether this be air, oil, or water) must make possible the attainment of the required minimum cooling rate.

Preliminary Treatment

It is good practice to carry out a preliminary homogenising treatment before proceeding to the hardening (or normalising) and tempering operations. The homogenising treatment can be done quite well in large, batch-type furnaces. The temperature attained by the castings should be between 900° and 950° C, or even as high as 975° C will do no harm provided it can be accomplished without excessive scaling. The ill effects of overheating are well known, as students we have all had them dinned into our ears, but this is no doubt to a large extent a legacy of the experience when hardening carbon tool steel, where it is a reality, and may be regarded more as a bogey when annealing steel castings. Indeed it is highly probable that more brittle steel castings are produced by the use of too low an annealing temperature than by the use of one that is too high. Apart from any other advantage that may be conferred on the castings, a preliminary heat-treatment is of assistance if much dressing with pneumatic hammers is required, because many of the high-strength steels are distinctly hard in the "as cast" condition. When softening is one of the objects, normalising and tempering, which can be done quite conveniently in the car-bottom, batch-type furnace without unloading, is usually more efficacious than annealing.

Hardening

A small crystal grainsize and sorbite derived from homogeneous martensite, rather than from tempered transition products, are generally agreed as necessary conditions in the production of hardened and tempered steel having the best all round mechanical properties. This used to be considered as setting a rather small range on the temperature above the Ac3 point that could be used if optimum grain size was to be obtained, but it is now possible to use a temperature considerably higher than the theoretical one without seriously influencing the result, provided that care was taken during the steel making operations to ensure steel having inherently fine grained characteristics; this has already been touched on when speaking of the influence of aluminium. Whether martensite or transition products will be formed during quenching depends on the chemical composition of the steel and the cooling rate. To have the cooling as uniform as possible is obviously desirable, and to ensure the free circulation of cooling medium there is a clear case for carefully thought out disposition of castings in charges that are to be bulk quenched.

For the steels under discussion we consider oil quenching to be more satisfactory than water quenching. For a variety of reasons, usually connected with cost or with domestic difficulties in the cooling of a quenching liquid, hot water is sometimes used for quenching, but this seems to have very few advantages and a number of disadvantages when compared with quenching in a suitable type of quenching oil efficiently cooled.

A good quenching oil should decompose as little as possible in contact with the hot steel being quenched; for this reason mineral oil is preferred to fish oil, and general considerations would seem to indicate the choice of a paraffinic type of base. In order to cool the steel efficiently, the hot oil must be able to move quickly from the surface and to be replaced by fresh oil; this requires that the oil should be of fairly low viscosity. Fire risks require a reasonably high flash point. These three properties—chemical stability, viscosity, and flash point, together with a desire that the oil should not contain hydrocarbons which evaporate at a relatively low temperature, constitute the primary requirements in a quenching oil.

Tempering

Tempering does not call for any comment except an observation on temper brittleness. If the steel is of a composition which is known to be susceptible to temper brittleness the necessity for quenching after tempering is indicated, for reasons of cleanliness water will generally be used as the quenching medium. The presence of molybdenum in amounts over about 0.2% is generally regarded as rendering the usual types of constructional steels immune from temper brittleness, and whilst this is true for wrought steels and usually for cast steel it does not always hold good in the case of steel castings. So far as the authors are aware the reason for this difference in behaviour has not been established, but as a plausible hypothesis they suggest the greater homogeneity of wrought steel as a reason for its more satisfactory behaviour. It is our practice to quench all alloy steel castings after tempering, irrespective of their chemical composition.

Mechanical Properties

The permissible ultimate tensile stress to be obtained from any particular type of steel is governed to a large extent by the ductility required. When the object is to make castings that are in the toughest condition it is not possible to obtain from steel all it is capable of in the matter of ultimate tensile stress. The object here was to have not only strong but tough castings and the ultimate tensile figures may, therefore, appear to some to be on the conservative side. There is a good deal of argument about the value of the Izod test, it is regarded here as a valuable one, and looked on as a ready means of

assessing (and expressing as a number), that quality of the steel which is judged in the eminently practical test of breaking up a casting and noticing the manner of breaking and the appearance of the fracture, or by notching a bar and breaking it in a vice.

TABLE VI.
MANGANESE-MOLYBDENUM STEEL.
Normalised and Tempered.
Casting Weight: 122 lbs. Maximum section 2 in.

Chemical Composition					Mechanical Properties							
C	Mn	Ni	Cr	Mo	Test Block				Casting			
					Y.P. t.s.i.	U.T.S. t.s.i.	E %	Izod ft. lb.	Y.P. t.s.i.	U.T.S. t.s.i.	E %	Izod ft. lb.
0.23	1.38	0.05	0.09	0.32	32.2	40.1	24	60	27.0	37.8	24	37
0.27	1.52	0.09	0.13	0.17	29.8	40.2	28	69	32.0	40.8	22	56
0.22	1.08	0.75	0.11	0.29	31.0	41.2	26	63	34.5	42.4	20	30
0.25	1.37	0.76	0.11	0.23	32.4	41.6	20	35	30.8	40.8	11	25
0.32	1.40	0.80	0.15	0.27	36.8	46.2	20	49	34.0	42.6	18	36

The Izod values of medium manganese steel (1 to 1½% with residuals) may vary widely. The steel appears to be affected by variations in the steel making practice, and if used in the annealed or normalised condition the Izod value of some casts of steel can be considerably improved by tempering. The presence of small amounts of residual elements, Ni, Cr and Mo improve the uniformity of this steel. The chemical composition and mechanical properties of a number of typical casts are shown in Table V in the normalised and tempered and quenched and tempered conditions. It will be seen that the manganese content has been reduced to allow for the residuals present.

Manganese-molybdenum steel has much to recommend it as a material from which to make strong, tough steel castings. In addition to its use in the quenched and tempered condition it has the advantage of responding well to the simpler treatment of normalising and tempering, so that a simpler treatment can be used when facilities for the full quenching treatment are not available. Tempering after normalising is essential for manganese-molybdenum steel (and for that matter after annealing also if it should be necessary to use this steel in that condition); a tremendous improvement in ductility and toughness, gained at the expense of some loss of strength, follows tempering. Some typical results

TABLE V.—MECHANICAL PROPERTIES OF 1% MANGANESE STEELS (CONTAINING RESIDUAL ALLOYS)
Size of Specimens when Treated: 1½" × 1½" × ¼".
Preliminary Treatment—Normalised 900°C.

Cast No.	Chemical Analysis					MECHANICAL PROPERTIES											
	C	Mn	Ni	Cr	Mo	Normalised 850°C. Tempered 600°C W.Q.						Oil Hardened 850°C. Tempered 600°C, W.Q.					
						Y. P. t.s.i.	U.T.S. t.s.i.	Yield Ratio %	E% on 2"	R/A %	Izod ft. lbs.	Y. P. t.s.i.	U.T.S. t.s.i.	Yield Ratio %	E% on 2"	R/A %	Izod ft. lbs.
A3251	0.22	1.01	0.82	0.13	0.18	28.4	35.6	80	31	57	68/72	31.9	38.4	83	29	58	69/69
A3252	0.21	0.99	0.75	0.15	0.19	27.2	34.0	80	33	63	94/98	28.4	37.0	77	30	60	87/90
A3254	0.21	1.02	0.81	0.13	0.17	27.5	35.2	79	32	61	69/83	32.6	38.1	85	30	62	81/85
A3255	0.23	1.27	0.81	0.12	0.18	28.1	39.8	70	30	58	84/88	36.2	43.7	82	25	54	75/75
A3256	0.21	1.04	0.92	0.14	0.16	27.2	36.4	75	32	60	60/72	33.0	39.8	82	29	60	61/63
A3257	0.21	1.10	0.96	0.12	0.16	31.1	39.2	80	28	54	60/62	34.8	42.9	81	26	56	61/62
A3258	0.21	1.10	0.72	0.09	0.21	28.0	36.6	79	33	65	95/95	32.3	39.0	83	29	60	89/91
A3259	0.19	1.08	0.74	0.09	0.21	29.0	36.6	79	31	61	78/80	33.6	40.8	83	26	57	79 81
A3260	0.21	1.11	0.72	0.13	0.17	28.0	36.0	81	31	58	64/67	31.8	38.6	82	27	56	60/60
A3261	0.20	1.10	0.70	0.14	0.17	29.2	37.4	78	31	59	77/80	33.6	40.5	83	29	62	77/83

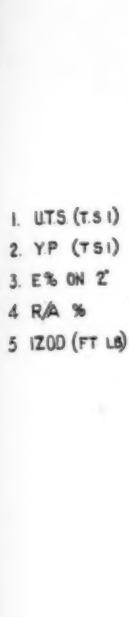


Fig. 10.—Influence of carbon on the mechanical properties of 1% Cr-Mo steels. Specimens $1\frac{1}{2} \times 1\frac{1}{2} \times 4\frac{1}{2}$ in. Oil quenched at 850-860°C and tempered at 550°C.

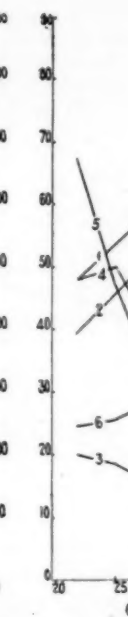


Fig. 11.—Influence of carbon on the mechanical properties of 1% Cr-Mo steels. Specimens $1\frac{1}{2} \times 1\frac{1}{2} \times 4\frac{1}{2}$ in. Oil quenched at 850-860°C and tempered at 600°C.



Fig. 12.—Influence of carbon on the mechanical properties of 1% Cr-Mo steels. Specimens $1\frac{1}{2} \times 1\frac{1}{2} \times 4\frac{1}{2}$ in. Oil quenched at 850-860°C and tempered at 600°C.

are shown in Table VI. Variations in tempering temperature have the same effect on quenched material as on wrought steels, and the usual range is from 550° C to 650° C. A number of the steels used are more or less interchangeable as can be seen from the results recorded in Table VII. The relationship between tempering and mechanical properties for a cast of manganese-molybdenum steel is depicted in the curves of Fig. 13 and for the most highly alloyed type of steel used in this work in Fig. 14. The latter steel has been used for castings of fairly thick section and considerable weight for which a minimum ultimate tensile strength of 55 t.s.i. was required.

More attention has been paid by engineers latterly to the properties of the material delivered to them in the casting as distinct from the results obtained from test bars. This trend should be welcomed, and in the long run it should be to the advantage of both the foundryman and his customer. At the same time every effort should be made by the former to convince the latter

that the best steel casting (unless it is of the most simple shape), is likely to contain some minute shrinkage cavities, and that if these occur near the surface of a tensile test piece the values obtained for elongation and reduction of area are bound to be affected adversely. In the authors' experience the Izod test is affected much less by the presence of such interdendritic shrinkage cavities than is usually the case with tensile tests. Considerably more might be done, they feel, to extend the use of Brinell hardness and Izod tests to supplement the older tensile and bend test-pieces, or even to replace them for certain applications. A number of the results reported in this paper enable a comparison to be made between the mechanical properties of separately cast test bars and the mechanical properties of castings which they represent.

Chemical Composition

The choice of an alloy steel for constructional purposes has in the past been directed by a number of considerations amongst which are the reputation it may enjoy

TABLE VII.—MECHANICAL PROPERTIES OF ALLOY STEEL CASTINGS
Quenched and Tempered to give 45-50 t.s.i. Ultimate Tensile Stress on Test Bar.
Test Bar $1\frac{1}{2} \times 1\frac{1}{2} \times 1\frac{1}{2}$ in. Casting Weight 206 lbs. Maximum Section $2\frac{1}{2}$ in.
Columns Headed 1.—Test bar results. Izod average of 3 notches.
" " 2.—Lowest result obtained from a casting, specimens taken from four different places, Izod lowest of 12 notches.
" " 3.—Highest result obtained from a casting, specimens taken from four different places, Izod highest of 12 notches.

CHEMICAL COMPOSITION					MECHANICAL PROPERTIES																	
C	Mn	Ni	Cr	Mo	Y.P. t.s.i.			U.T.S. t.s.i.			Yield Ratio			Elong. %			R. of A. %			Izod		
					1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0.23	1.53	1.04	0.21	0.32	30.9	35.3	35.6	47.2	43.6	44.1	84.5	80.4	81.1	20	15	22	44	28	44	73	80	87
0.26	1.48	0.94	0.11	0.36	40.9	38.9	40.9	49.0	43.7	48.1	83.5	84.1	89.1	20	13	16	40	18	34	66	65	73
0.30	0.96	0.68	1.00	0.30	38.8	38.8	39.3	49.8	48.5	49.4	78.0	79.5	80.0	17	16	18	35	20	38	51	36	42
0.23	0.70	0.50	0.82	0.25	35.3	35.2	36.2	45.1	42.2	46.0	78.2	78.8	83.5	16	8	17	33	15	33	56	38	60
0.30	1.20	1.30	0.14	0.19	37.8	35.8	36.8	47.8	44.8	46.9	79.2	78.5	80.0	20	10	22	38	27	42	65	61	68
0.30	1.23	1.54	0.10	0.16	37.4	35.2	38.2	47.2	44.5	47.1	79.3	79.2	81.9	19	13	21	39	27	33	52	53	60
0.24	0.76	2.14	0.21	0.20	36.8	35.6	35.7	45.1	42.6	43.1	81.5	82.8	83.6	21	16	24	48	31	54	80	70	82
0.24	0.91	1.70	0.21	0.15	36.4	36.3	37.7	45.4	44.2	45.0	80.3	82.0	84.4	24	21	25	51.5	31	52	76	73	80

through long established successful usage, and personal experience or prejudice of the designer or metallurgist, and development work done by groups interested in expanding the use of certain alloys. The foundry industry seems to have tended much more towards "unusual" compositions than the producers and users of wrought ferrous materials. Latterly the urge to establish national self sufficiency has done much towards the displacement of the older alloy steels by other compositions. In Germany, during the last 15 years, for instance, the use of steels relying largely on manganese and silicon, fortified with one or more of the elements chromium, molybdenum and vanadium, and the exclusion of nickel has been a marked development both for wrought steels and castings.^{10, 11} Since the war all steel-producing countries have been faced by serious shortages of alloys. Of all the established alloying elements added to steel manganese is the one that exerts the most pronounced effect and as it is also the cheapest it is natural that the trend has been more and more towards the use of this element, because, after all, the composition which will give the required properties for the smallest cost will be the logical choice, at least in peace time.

When outlining the scope of the paper it was indicated that the steels to be considered would include carbon-manganese steel (with residual alloys) equivalent to about 1.5% manganese, manganese-molybdenum steel (1½% Mn), chromium-molybdenum (1% Cr), 2½% nickel-chromium-molybdenum, and non-standard steels containing rather large amounts of residual elements. The greater part of the steel made has been of either the manganese or manganese-molybdenum varieties (the use of chromium-molybdenum steel has been discontinued in favour of the latter). A number of the steels are more or less interchangeable as can be seen from the mechanical tests recorded in Table VII. The really high-alloy steels have been used only when castings of considerable section requiring high tensile strength were to be made.

The carbon content is held as low as possible consistent with obtaining the necessary combination of ultimate tensile stress and ductility. A low carbon is desired because it reduces the danger of cracking and eases fettling operations, and the steel is less likely to acquire a dangerous combination of hardness and brittleness if welding has to be done at a stage when any subsequent tempering or stress relieving is no longer possible. There is, of course, a limit to this reduction of carbon, for instance, when a fairly high tempering temperature is to be used (and this is generally desirable) and the ultimate stress demanded is high for

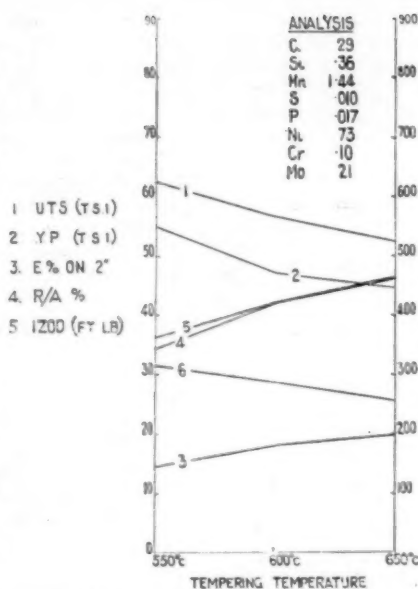


Fig. 13.—Influence of tempering temperature on cast steel. Specimens $1\frac{1}{2} \times 1\frac{1}{2} \times 4\frac{1}{2}$ in. Oil quenched at 850-860°C and tempered as indicated.

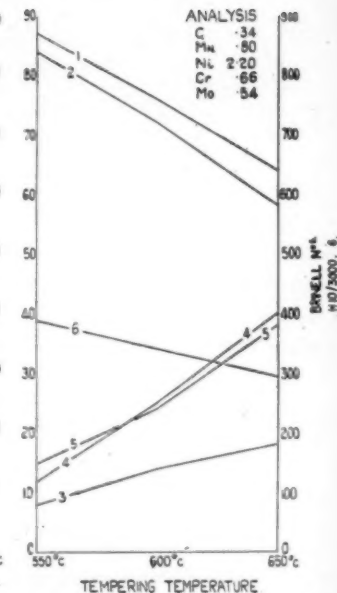


Fig. 14.—Influence of tempering temperature on cast steel. Specimens $1\frac{1}{2} \times 1\frac{1}{2} \times 4\frac{1}{2}$ in. Oil quenched at 850-860°C and tempered as indicated.

the type of steel, then an increase in carbon must be made. The influence of carbon on the mechanical properties of 1% chromium-molybdenum steel is well illustrated by the curves of Figs. 10, 11 and 12.

Mould Sand

Dry sand moulding is general in this steel foundry. The sand system is not yet fully mechanised, consequently in the preparation of sand a rather large proportion of new sand is required to counteract the cumulative effect of silt and to ensure the most satisfactory results. The facing sand and backing sand are prepared, at the present time, separately. About a third of the total sand in circulation is prepared facing sand. The backing sand is reconditioned on the knock out floor and returned to the moulding section. A portion of the knocked out sand is returned to the sand mill as old sand.

The bases of the moulding sand are a strongly naturally bonded sand containing 20 to 25% of clay and a clean washed silica sand of medium grain fineness. For the preparation of facing sand a Smedley mill with two 10-cwt. rollers is used. Sand is milled for four minutes and then passed through an aerator. The ordinary mould sand is made up of old and new sand in approximately equal amounts. In practice the proportion of new sand varies between 40% and 60% as required to keep the properties constant. The new sands are added separately to the mill but usually in the ratio of 6 parts of the bonded sand to 4 parts of the silica sand. If an all new sand mix was required for some special job this 6 : 4 mixture would be used.

The laboratory has the responsibility for the correct preparation of the sand. Samples of new sand as delivered are taken at intervals to check their chemical and physical properties. About half the mould sand mixtures made each day are tested, the A.F.A. Standard

10 H. Juretsch, Alloy Steel Castings, Their Properties and Application. Giesserei, 1942, vol. 29, p. 217.

11 A Metallurgical Study of German and Italian Aircraft Engine and Airframe Parts. The Aero Component Sub-Committee of the T.A.C. The Kennedy Press Ltd., 1943, p. 84.

methods and testing apparatus are used. Tests are carried out on each sample to determine moisture, green compression strength, dry permeability and dry compression strength. The clay content is determined periodically by the A.F.A. method. The desired properties are:—

Moisture	7.0%
Green Compression Strength	7.0 p.s.i.
Dry Permeability	120 A.F.A. No.
Dry Compression Strength	250 p.s.i.
A.F.A. Clay Content	15.0%

These test figures have been found after much experience to be linked up with the best all round results from the sand. The figures obtained from the daily tests are recorded in chart form and are accompanied by a record of changes in the mixture and notes of any defects that could be attributed to the sand.

TABLE VIII.

Natural Bonded Sand % by vol.	Washed Silica Sand % by vol.	Old Sand % by vol.	Bentonite % by vol.	Cereal % by vol.	Green Comp. Strength p.s.i.	Dry Perm. A.F.A. No.	Dry Comp. Strength p.s.i.
30	20	50	—	—	7.0	120	250
60	40	—	—	—	7.2	120	300
60	40	—	1.0	—	7.7	115	350
60	40	—	—	1.0	8.0	110	450

In defining the best proportion of the mould sand, consideration must be given to the type of moulding (i.e., machine or hand rammed) the degree of ramming, effect on pattern drawing and the designs of castings in production. The most desirable permeability or the highest dry strength obtainable with mixtures of the two sands are not those of the most workable sand. For instance, the effect of moisture on properties is such that the dry strength increases as the amount of moisture present at the time of milling is increased, but the sand is not so workable with the higher moisture content. With a higher proportion of the bonded sand the sand becomes too tough and difficult to ram and the higher dry strength obtainable is offset by the loose ramming of those parts of the mould where a high dry strength is most needed.

When high dry strength is desired, Bentonite or Cereal binder may be added to the mixture without greatly affecting the permeability and it has been found better to increase strength in this way rather than by making a big increase in the proportion of naturally bonded sand with its accompanying lowering of permeability. As will be seen from the data in Table VIII the maximum dry compression strength obtainable in the A.F.A. specimen with the naturally bonded sand alone is only 250/300 p.s.i., and although this is high enough for many purposes it may be increased to 350 or 450 p.s.i. if required by the addition of 1% by volume of Bentonite or cereal binder. These may also be used to keep up the strength whilst the permeability is improved by an increase in the proportion of the larger grain silica sand.

When the permeability falls below 80 (A.F.A. Number) scabbing will occur on hard rammed surfaces. A low permeability is usually an indication of an excess of silt in the sand and is accompanied by a tendency for sand to fuse and adhere to castings. These troubles will occur if too great a proportion of old sand is being retained in circulation.

Core Sands

A large number of core sand mixtures can produce satisfactory results in the steel foundry depending upon

the circumstances in which they are used. Most of the work can be produced with three main mixtures, with modifications to meet the requirements of any special work.

Three clean silica sands are the bases of all the core sand mixtures and no reclaimed sand has been used. The sands are:—

Leighton Buzzard (No. 1 coarse),
Chelford,
Southport Hill Sand.

These three sands may be mixed or interchanged to bring about variations in permeability.

For most purposes the sand bonded with 3.0% semi-solid core cream gives satisfactory results. This mixture has a fairly high green bond strength which makes it suitable for most designs, so far as the core making is concerned. Where a specially weak core is required to avoid the formation of strains or hot tears a sand bonded with a cereal and pitch binder plus linseed oil is used. It has a low hot strength. When it is necessary to have a strong core together with the minimum hot strength it has been found advantageous to have as high a proportion of coarse sand as possible in the mixture as the increased rate of flow of hot gases through the cores promotes a rapid disintegration of the sand.

The average properties of the core mixtures are shown in Table IX but these are modified somewhat by the grain size of the sand when a fixed amount of binder is present.

TABLE IX.
Properties of Core Sands. A.F.A. Specimens baked 1 hour at 200° C.

Sand Mixture (% by Weight)	Green Comp. Strength p.s.i.	Dry perm. A.F.A. No.	Dry Comp. Strength p.s.i.
Chelford Sand	2.5	200	1500
Semi-solid Core Cream, 3.0%			
Chelford Sand	2.0 to 2.5	200	400 to 800
Cereal and Pitch Compound, 2.0%			
Raw Linseed Oil, 0.25 to 0.75%			
Water, 4.0%			
Chelford Sand, 50 to 100%	1.5 to 2.5	200 to 300	2000 to 3000
Leighton Buzzard, 0 to 50%			
Cereal, 1.0 to 1.5%			
Silica Flour, 1.0 to 1.5%			
Raw Linseed Oil, 1.0 to 1.5%	1.5 to 2.5	200 to 300	2000 to 3000
Water, 4.0%			

Methods of Feeding

Much attention has been paid during the last few years to methods of feeding in an endeavour to get hot metal where it is wanted for feeding without introducing difficulties which more than offset the advantages gained, the whirl-gate and atmospheric pressure head are two of them. The thanks of foundrymen should go out to the investigators who have worked on these problems. It is not intended here to attempt any discussion but to point out a difficulty which is sometimes met when the top of the atmospheric head is at a level considerably lower than the top of the casting to be fed. The steel in its passage through the mould usually collects a certain amount of sand and refractory material which floats upwards on the surface of the rising metal, if the top of the mould is closed this pasty or liquid slag is trapped against the top surface and may form a hot spot which will keep the metal around it hotter for a time than the rest of the freezing and cooling envelope, long enough perhaps for the runner to freeze

12 H. F. Taylor and E. A. Rominski. Atmospheric Pressure and the Steel Casting—A new Technique in Gating and Riser. T. of the A.F.A., 1942, vol. 50, p. 215.

whilst the steel around the small hot-spot is still plastic enough to burst through by atmospheric pressure, and the conditions now being the same both in casting and head feeding can no longer take place. When repeating some of Taylor and Rominski's experiments¹² on a casting similar to one of theirs in shape and method of running and feeding the present authors found some good examples of this behaviour. A casting 9 in. high \times 1 $\frac{3}{4}$ in. \times 3 in. connected to a side head and intended to be fed by atmospheric pressure is shown in Fig. 15. After solidifying to give a uniform layer of about $\frac{1}{2}$ in. of solid steel there appears to have been a rapid subsiding of the still liquid metal in the casting, examination showed the atmosphere to have had access to the interior of the casting by means of a fine pin hole connecting at the surface with an area that had been kept hot by a small globule of slag or fused sand. The level of the metal in the casting has not fallen as low as one would have expected, for although having a somewhat porous structure below the main cavity (the porosity is not shown clearly in the illustration) the metal was

sound at a level of about 1 in. above the top of the blind riser. Without going into possible explanations for the peculiarities in behaviour the example illustrates one of the dangers to be guarded against with this type of feeding. When a chill was placed at A, thus ensuring quick freezing at the surface where hot-spots might occur, the casting solidified solid with atmospheric pressure feeding.

It has become usual to regard the method of feeding which uses

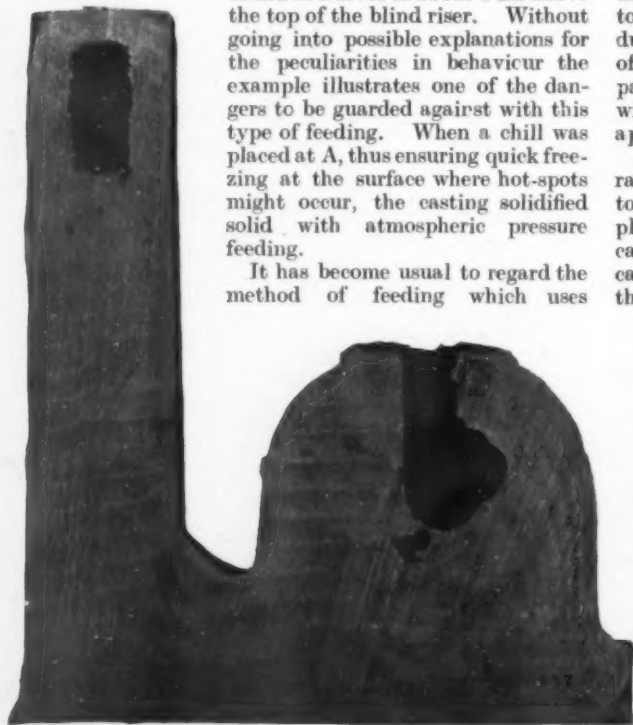


Fig. 15.—Section of a side head on a casting intended to be fed by atmospheric pressure.

hydrostatic head and gravity as "gravity feeding" and the vented blind head and closed mould as atmospheric pressure feeding, but it may not be out of place to remark in passing that each of these methods depends on gravity, the pressure exerted by the atmosphere is itself dependent on gravity.

Quality

The future for the use of steel castings is quite good but it will only be developed on the basis of quality and

it is on this particular point, failure to satisfy the user, that much trade has been lost to the drop forging and malleable iron industries.

Certain sections of the engineering trade would welcome steel castings if there was greater certainty of consistency in the physical properties of the steel, much fewer blow holes, and less porosity in the sections, with cleaner delineation of the outside shapes.

Loss of money and production to the user is not measured by the number of rejected castings but by the total time in addition spent on machining the pieces which in many cases are on the point of completion before the need for rejection becomes apparent.

To meet this position the authors hope shortly to establish the practice of radiological examination much on the lines adopted by the Light Metal Industry, wherein most important castings for aero engines and under-carriages have been produced in large quantities and under meticulous inspection. Most foundries in metallic alloys have difficulties with the manufacture of castings for prototype designs but the time factor of delivery generally allows some latitude for experimenting to overcome them. In competitive business for production quantities such help is not available and more often than not the foundryman has to call upon his past experience to decide upon the best way of making, without any immediate proof of success, before an appropriate quantity has been delivered to the customer.

The assistance needed therefore, can be had by radiological examination. Where strange designs are to be made without delay in production quantities, the plan of examination recommended is that the first six castings produced should be X-rayed; usually results can be obtained the day following. The more powerful the X-ray unit the quicker can results be given, for steel castings in particular, a machine of 400 kvA will meet an all-round purpose.

In this way direction is given whether a revision of the method of making is necessary. Where the correct line has been adopted or is ultimately achieved, the process of examination is continued over fifty per cent. of say the first fifty or hundred castings produced.

Should the results from the larger quantities be satisfactory then it is a fairly safe basis upon which to proceed for larger production, it is advisable then to take samples at random to ensure continuity of quality until the completion of the order.

The interpretation of the results of radiological examination is simplified by acquaintance with the negatives produced. When full access to them is given to the foundrymen, it is surprising how quickly he becomes so minded to use such examination and be guided by what he sees for himself.

Personal

Mr. W. A. Archibald, B.Sc., Technical Manager of the Glenboig Union Fire-Clay Co. Ltd., has graduated Ph.D. at Glasgow University (on June 22nd). The title of his thesis was "The Study of the Physical Constants of the Components of Steel Furnace Slags." Dr. Archibald has been with the Glenboig Company for the last 6 years and is in charge of the technical activities of that Company.

Segregation of Metals and Alloys

Some aspects on segregation which were presented in a recent symposium before the American Institute of Mining and Metallurgical Engineers are discussed. They deal with fundamental principles involved in segregation of alloy castings, factors underlying segregation in steel ingots, the relation of open-hearth practice to segregation in rimmed steel, and segregation in babbit metal.*

SEGREGATION is a persistent problem with all metals and alloys. It is particularly troublesome in steel ingots containing appreciable amounts of impurities and this aspect was included in a series of papers, forming a symposium on the subject, before a recent meeting of the American Institute of Mining and Metallurgical Engineers. In all, four papers were presented, the main features of which are considered in this review.

Fundamental Principles

In the first paper, R. M. Brick considered that fairly rapid solidification of an alloy over a range of temperature leads to metastable conditions of coring within solid solution dendrites and an associated abnormal enrichment in low-melting-point constituents of the final liquid to freeze. The dendritic form of solidification leaves interdendritic channels, which, filled with low-melting-point constituents, reduce the tremendous composition difference found in cored structures (microsegregation) to relatively low differences on the macro scale. The formation of internal gas bubbles creates a positive pressure, forcing low-melting-point liquid to the surface, and forming in extreme cases exudations. A more fundamental consideration involves contraction and associated low-pressure areas in interdendritic channels, and this concept must be amplified by the conception of segregation in the liquid phase, i.e., an enrichment in lower-melting-point constituents at the solid-liquid interface. The flow of enriched liquid through channels may in some cases be sufficient to cause inverse segregation, but there is no clear explanation on how to control the statistical distribution of the last liquid to freeze or relatively the type of segregation. Three forms of gravity segregation may be found all dependent on a marked difference in density between liquid and solid phases or between two liquid phases.

Segregation in Steel Ingots

In reviewing factors underlying segregation in steel ingots, B. M. Larsen dealt with temperature gradients and heat dissipation during freezing, the directional growth of crystals, selective freezing and diffusion, dendrite formation, grain size orientation in outer ingot zones, settling of free-floating dendrites, effects of liquid motion and stirring caused by gas evolution, freezing of a typical rimmed ingot, a transition series of ingot structures with decreasing gas evolution, hydrogen evolution during solidification, and the segregation of oxygen and non-metallies. Summarising some of these factors the following were selected as significant effects that occur in the various types of steel ingots or other castings:—

(1) The heat evolved in freezing, the outflow of which determines the rate and sometimes the direction of the

crystal growth; (2) the tendency of skeleton types of crystals, such as dendrites, to grow faster along the original axis of growth than in other directions; (3) the higher iron content of the crystal nuclei, thus leaving an adjacent layer higher in impurities and lower in freezing point; (4) the fact that as a result of these concentration gradients a rate of diffusion of mixing is introduced to limit the rate of freezing, thus favouring the dendrite form of crystal growth, which can, however, be suppressed or at least very much changed in character by such vigorous stirring as will practically eliminate these concentration gradients; (5) the high specific gravity of iron, involving a large kinetic energy storage in vigorous stirring and a large increase in ferrostatic pressure between top and bottom ingot zones; (6) the very appreciable difference in specific gravity between liquid metal and solid crystallites. This is not so large in terms of percentage (about 7%) but the absolute difference is equal to about half the specific gravity of water, thus allowing for rather rapid settling of unattached dendrites; (7) evolution of gas by the carbon-oxygen reaction in iron solution with gas-bubble formation favoured by a somewhat rough, solid surface, its repression by increased ferrostatic pressure, the wide variation in the reaction tendency with variable oxygen content in the liquid steel, and the importance of the stirring and blowhole-forming effects of this reaction.

Segregation in Rimmed Steels

The relation of open-hearth practice to segregation in rimmed steels was discussed by J. W. Halley and J. L. Plimpton. The mechanisms producing segregation were first treated with respect to such factors affecting segregation as differential solidification, the removal of constituents as reaction products, the efficiency of film removal and the ratio of rim zone to core zone. Consideration was then given to the effect of practice on segregation and factors which affect the segregation mechanisms in a major degree such as the concentrations of carbon, oxygen and manganese, the segregation of sulphur, the steel temperature and mould conditions, such as temperature and design, which govern the freezing rate of the steel in the mould, and capping practice which determines the extent of the rim zone. Finally, examples of segregation in rimmed ingot are dealt with.

From this survey of the phases of open-hearth practice that influence the mechanisms producing segregation, it was shown that the desirable type of segregation in the rimmed grade of ingot consists of maximum negative segregation in the rim zone and minimum positive segregation in the core. When summarised, the possible controls that may be applied to the mechanisms producing this type of segregation are that the composition of the steel with respect to elements not subject to elimination from the ingot as reaction products, must be held in low values, particularly when their segregation

* *Metals Technology*, 1944, Vol. 11, No. 6, A.I.M.M.E. Technical Publication No. 1764, 88 pages.

coefficients are high; that the desired vigorous motion of the metal, which removes impurities from the solidifying surface, may be secured by maintaining a high carbon-oxygen product, a rapid freezing rate, and a low pouring temperature; and that by checking the rimming action as early as possible by capping the ingot, segregation in the core zone may be reduced.

Distribution of Elements in an Alloy-Steel Ingot

The fourth paper of the symposium dealt with the results obtained from an investigation by S. W. Poole and J. A. Rosa to determine the distribution of chemical elements within a large killed alloy-steel ingot by sulphur-printing and quantitative chemical analysis. A charge of nickel-chromium-molybdenum steel, mostly in the form of heavy mill scrap, was melted in a 70-ton direct arc-type basic electric furnace and cast into a 34,000 lb. ingot at 1555° C. After the standard annealing, the ingot was heat-treated at 540° C. for 12 hours, a slice 4 in. thick was cut near the longitudinal axis for sulphur-printing, macroetching and analysis, and this slice of the ingot was heat-treated further for 12 hours at 650° C. and air cooled.

The calculated composition was established by averaging the 20 outer zone determinations of each element. These values, together with the ladle analyses

TABLE I.—AVERAGE VALUES OF CONSTITUENTS IN ALLOY STEEL INGOT.

Sample Position.	C	Mn	P	S	Si	Ni	Cr	V	Mo
Ladle	0.380	0.65	0.012	0.014	0.30	1.86	0.81	0.07	0.34
Outer Zone ..	0.379	0.655	0.0103	0.0149	0.313	1.86	0.826	0.066	0.347
Average ..	0.379	0.655	0.0103	0.0149	0.313	1.86	0.826	0.066	0.347
Ingot Average (51 Positions)	0.3.4	0.66	0.010	0.015	0.31	1.86	0.82	0.07	0.35

and the average values of 51 determinations within the ingot body proper, are given in Table I. The average composition of the rapidly solidified outer zone is used as a basis of comparison of element segregation within the ingot. In view of the mass of the ingot, the distribution of elements is remarkably uniform. Study of the quantitative chemical data plotted on the sulphur prints indicates, with respect to segregation in the ingot body, that (1) all elements segregate to some degree; (2) major segregation occurs in the same general area; (3) all segregation in these areas apparently is of the inverse order. Of the nine alloying elements composing the analysis of the steel, carbon segregates to the greatest degree, while vanadium is the least affected. Nickel and manganese appear to be next in order in the magnitude of segregation. Sulphur and phosphorus in the body of the ingot did not show the degree of segregation expected. Most of the segregation occurs in the lower third of the ingot and is of the inverse order, the region being definitely impoverished in alloying elements. Slight enrichment of manganese and sulphur occurs in the upper third central portion of the ingot, but other elements do not appear to be affected.

Segregation in Babbitt Metals

Segregation in white bearing metals, was dealt with by T. E. Egan and W. R. McCrackin. Two compositions of white metal were investigated: one a tin-base and the other a lead-base alloy. As bearings are usually cast either statically or centrifugally, the effect of these two methods of casting was dealt with. In the statically

cast experiments, slabs $\frac{1}{2}$ in. thick by 5 in. wide and 17 in. long, were cast, using a book mould with the long edge vertical. One slab for each alloy was made by allowing the metal to cool without stirring and the other slab was stirred during the entire cooling cycle. In the centrifugal casting tests, similar alloys were cast into shells $7\frac{1}{2}$ in. in diameter. In each case one shell was allowed to spin without accelerated cooling until the metal was solid, and in the other case, the metal was chilled. Chemical, macroscopic and microscopic examination was made of all samples and the results of the chemical tests are given in Tables II and III.

TABLE II.—CHEMICAL ANALYSIS OF WHITE METALS—STATICALLY CAST.

Position	Tin-Base.				Lead-Base.					
	Not Stirred		Stirred		Not Stirred			Stirred		
	Cu	Sb	Cu	Sb	As	Sb	Sn	As	Sb	Sn
Top	3.44	7.69	3.38	7.67	1.13	14.7	1.21	1.14	13.9	1.13
Middle	3.45	7.53	3.40	7.40	1.14	15.1	1.20	1.12	14.0	1.1
Bottom	3.46	7.50	3.42	7.62	1.12	14.7	1.11	1.08	14.0	1.05
Pot Analysis ..	3.46	7.48	3.46	7.48	—	—	—	—	—	—

TABLE III.—CHEMICAL ANALYSIS OF WHITE METAL—CENTRIFUGALLY CAST.

Position.	Tin-Base.				Lead-Base.					
	Not Chilled.		Chilled.		Not Chilled.			Chilled.		
	Cu	Sb	Cu	Sb	Sb	Sn	As	Sb	Sn	As
Inside	1.22	7.78	2.65	7.83	16.50	1.51	1.08	17.20	1.38	1.61
Halfway Through	3.61	7.63	2.97	7.43	14.82	1.41	1.01	17.37	1.13	1.27
Outside	5.85	7.19	4.63	7.23	11.40	0.91	0.52	12.48	0.98	0.38
Pot Analysis ..	3.45	7.48	—	—	14.95	1.25	1.01	—	—	—

The analyses of the statically cast tin-base alloy show no serious amount of gravity segregation and microscopic examination from edge to edge of the slab showed little change in structure. The analyses of the statically cast lead-base alloy all show little or no segregation of the constituents, but a considerable difference in microstructure was found with the structure of the unstirred sample much finer than that of the stirred sample. Both the microexamination and the chemical analysis of the centrifugally cast tin-base alloy show that there is a great amount of segregation of the copper-tin compound towards the outside diameter of the shell and a concentration of the antimony towards the inside diameter. In the centrifugally cast lead-base alloy, there is a segregation of the antimony, tin and arsenic to the inside of the bearing. The cooling rate and the speed of spinning have a profound influence on the amount of segregation obtained.

It is also considered that cooling rate has a great influence on the segregation obtained in white bearing metals, therefore, the major factors that control cooling rate, such as the temperature of the jigs, fixtures and backings; pouring temperature of the metal; design of bearing back; design of jigs and fixtures; and thickness of metal, have to be given considerable attention. The addition of small amounts of metals, rather foreign to the composition of the white metal itself, such as tellurium, which act apparently to control grain size, also help to control segregation. These metals form nuclei from which crystallisation starts and also act as inoculents, which control the amount of supercooling. In the tin-base alloy, tellurium tends to suppress the formation of cubic Sn Sb crystals.

Investigation of Metal Pouring by Ciné Photography

A new technique developed to enable the examination of the flow of metal as it enters a mould.

TO look through a mould and observe the behaviour of the metal at the time of casting has been the desire of many foundrymen. The prospect of meeting this desire is drawing nearer as a result of a preliminary investigation described by C. L. Fry in a paper presented at the recent Annual Meeting of the Institute of British Foundrymen.

Using indirect radiography it was decided to investigate the possibility of examination with the fluorescent screen. Several types of crystalline screens are available which have the property of fluorescing under the action of X-rays. They give a visible indication of the presence of the X-ray beam and the use of this method is known in radiography as screening. By interposing an object between the X-ray tube and the fluorescent screen a shadowgraph of the specimen can be seen on the screen. In the application of this technique to the problem in hand, the X-ray tube was placed behind the mould and the fluorescent screen in front, and the resultant image of the mould was examined on the screen. The mould had to be severely limited in size, but when this condition was met, a clear picture of the mould shape and the flow of the metal could be seen. A logical development of this was to photograph the screen, which meant that, although the pictures could be taken very quickly, each individual negative could be studied later and information could be obtained at every stage. A diagram of the arrangement is shown in Fig. 1.

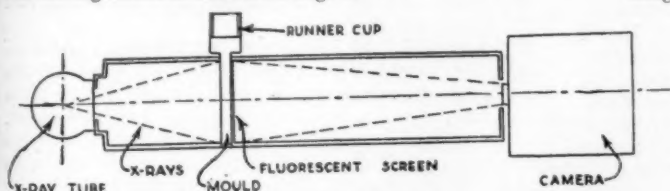


FIG. 1.—DIAGRAMMATIC SKETCH OF THE APPARATUS USED.

A few runs were made using a 35 mm. still Robot camera and, after a few trials, it was obvious that the method was a success, although with the particular camera in use it was impossible to obtain either a sufficient number of pictures or the desired frequency, and the next experiments were made with a 16 mm. ciné camera with *f.* 1.5 lens, and varying speeds and single picture device. A number of exploratory pours were made in lead, which was selected for its ease of melting and high density. The resultant pictures had a high contrast, a great advantage, because of the wide difference in X-ray absorption between the heavy lead and the comparatively light sand.

The original intention was merely to get flow or silhouette pictures of the metal, but subsequent results showed very much wider possibilities. Nevertheless, these early pictures gave encouragement, for they showed quite clearly the shape of the metal flow from the gate and how the mould was filled. Some pours were

then made in aluminium, and due to the much lower density compared with the lead, there was a considerable drop in contrast. It was then realised that if a slight increase in penetration could be secured, it would be possible to record internal details of the mould and casting with the same exposure.

First, the overall contrast of the method would have to be stepped-up to give sensitivity and, as the X-ray set was working at maximum output, the extra penetration would have to be obtained by adjustment to the camera, the film or the screen.

Results demonstrating the effect of different people pouring, runner shapes, casting shapes and the formation of gas bubbles and shrinkage cavities had been obtained and all proved to be very encouraging. Further improvement to the technique was, therefore, made and the stage reached when the apparatus could be used for investigations. The experimental data arrived at are summarised in Table I. It should be noted, however, that these conditions represent the best way of using the apparatus available to Mr. Fry for the particular technique developed. No suggestion is made that they represent finality, nor that with different apparatus improved results could not be obtained.

TABLE I.—Summary of Experimental Conditions.

X-ray Equipment :—

Siemens Schuckert 140 Kv. Set.

Target size 2.3 mm. square two-valve rectification.

Run at 140 Kv. 8 mA.

Distance of Target from mould 1 ft. 4 in.

Mould :—

Supinol AA. Sand Thickness, 1 1/4 in.

Maximum Thickness of casting, 5/8 in.
in L 33 Alloy.

Fluorescent Screen :—

Levy West AYS.

Distance of screen to front of lens,
2 ft. 3 in.

Camera :—

Erneman 35 m/m. Ciné Camera fitted with 5 cm.
f. 1.5 Sonnar lens.

Driven by electric motor.

Film :—

Ilford GX.

Developer :—

Ilford Blue Label (I.D./42) for 10 mins. at 70° F.

Bromide Paper :—

Ilford Glossy, No. 5.

From the series of cinégraphs reproduced with the paper it is clear that the method has great possibilities, and will be of considerable use to the practical foundryman, the die caster and also to the metallurgist. It has been indicated that up to the present a very general line of investigation has been followed, but it is suggested that future work could more advantageously be done by dividing into two sections. The first, probably of greater importance in the long view, is

the high-speed super-critical examination of thin layers of metal, with subsequent magnification of the results. The second, of more interest to the man who has got to make the casting, will be the development of the technique until much larger castings can be examined under production conditions. There is a promise of immense strides in X-ray output, in lenses, films, developers and fluorescent screens, each one of which will contribute appreciably to a widening of the scope of this definitely practical proposition. It may also be possible at a later date to amplify the screen brightness by means of television, and this will help even further in the future progress of the method.

Although the results given in this paper have been of use and have shown what has often been surmised, the full possibilities of the technique are not even indicated. In the foundry alone it should help to raise the casting process to a much more exact science, whilst in testing and in general applications there does not appear to be any limits to its ultimate use.

Discussion

Mr. D. Sharpes asked if the apparatus could be used to obtain definite information as to the manner in which the metal travelled along the face of the mould. The first advantages of the technique, replied Mr. Fry, were that it did show the pour of the metal. Generally speaking, the flow was not governed by the shape of the mould, but by the shape of the gate, the direction of the runner and pressure of the metal. There were numerous examples where the jet forced its way through the accumulating metal in the mould and over the top, filling the mould from the top face of the metal already in the mould.

Mr. T. H. Turner congratulated Mr. Fry and Messrs. Kent Alloys, Ltd. on having given information such as one would expect to come from a research organisation. The Company was certainly progressive, and he hoped it would derive great benefit from the work. No doubt, he continued, the use of gamma rays had been considered, and he asked why gamma rays had not been used. In his experience, so far as steel was concerned, the life of X-ray tubes was relatively so short that the maintenance of the X-ray plant became expensive. Therefore, one might just as well put capital into a radium source since there was practically no capital loss. Gamma rays should be considered as an alternative to X-rays for steel.

Commenting on the reference made to the flow of the metal in the mould, he said that he was more interested in the casting when it was made, and the tragedy of the use of X-rays or gamma rays was that, whereas they could detect blowholes, they did not show small cracks. Even some of the small blowholes were not detected. When a casting was cut up, cracks could be seen even with the naked eye which the X-rays did not show.

Mr. Fry, dealing with the question concerning the use of gamma rays, said that although he had had every encouragement from his Company, he had had to use the apparatus employed on the routine examination of aircraft castings. That apparatus comprised a 200 kv. set and a 140 kv. set. At the moment the 140 kv. set was being used; so that it was not a question of kilovoltage, but rather of milli-amperes. He imagined that when using gamma rays there would not be nearly enough energy to make the screen fluoresce brightly

enough; the output was very low from radium, and he did not think it would do the job. One did not need short wavelengths, but one needed a lot of medium wave-lengths just to make the screen bright.

With regard to the point that X-rays could not pick up cracks or other fine defects, he said the radiologist would never claim to be able to detect cracks, but would probably claim everything else. The laboratory could pick up quite a lot by means of X-rays when using thin sections, because all the defects were added up into one plane, and very often there was difficulty in confirming the defects by metallographic means. However, very often the radiologist could and did detect cracks.

Continuing, Mr. Fry said that he was interested only in aluminium castings, and he agreed that thick steel presented quite a different problem. Probably, at a later date, with the higher powered sets, sensitivity would increase.

Mr. Cox asked whether Mr. Fry had applied his technique to magnesium alloys, in which gas was not so bad as in aluminium, but where there were oxide inclusions and certain forms of microporosity.

Mr. Fry replied that he had not applied the technique to magnesium yet, but it was planned to do so. Some further progress would have to be made before micro defects inside the metal could be picked up; no doubt that would come, but it would be necessary to use more powerful equipment and much finer films. The limit of resolution was determined by the grain of the film and of the grain of the fluorescent screen. If there were more power so that those factors could be ignored and much more critical results could be obtained, he could also speed up the exposure. At the moment it was about 1/60th-second; with more output that could be brought down to anything for the sake of definition.

Mr. Gladwell asked whether fogging of the film had been experienced.

Mr. Fry said it had been anticipated that the use of lead glass would have been necessary; most of the Zeiss lenses, however, were made of fairly heavy glass and it was not necessary to use lead glass, but, at present, he was using a very thin sheet of lead glass merely to protect the lens from any deterioration which might be caused by the X-rays. Even without the lens in, the shutter passed over so quickly that there was no fogging of the film at all.

Control of Chrome, Magnesite and Wolfram

The Minister of Supply has made the Control of Chrome, Magnesite and Wolfram (No. 4) (Revocation) Order, 1945, revoking the Control of Chrome, Magnesite and Wolfram Orders (No. 1) of 1940, (No. 2) of 1941, and (No. 3) of 1942, by which the disposal and acquisition of chromium, chromium compounds, magnesite, wolfram and certain basic or neutral refractory materials were made subject to licence. The Order removes all existing restrictions on sales and purchases of these materials in the United Kingdom. Imports will remain for the present subject to the import licence procedure.

Copies of the Order, which came into force on 4th July, 1945, may be obtained from H.M. Stationery Office, York House, Kingsway, W.C.2, on and after that date, price 1d. (S.R. & O., 1945, No. 792).

MICROCHEMISTRY

APPARATUS · METALLURGICAL APPLICATIONS · TECHNIQUE

"WHEN is a microchemist a microchemist?" This paraphrase of an old query is prompted by a remark of Mr. Chirnside, in his inaugural address to the Physical Methods Group, already recorded in these columns. Mr. Chirnside, in referring to a method of gas analysis, comments that it handles considerably smaller quantities than any method of the microchemist. But the implications of this claim seem to go deeper than is justifiable. A microchemist, as we see it, is one who performs chemical operations, or produces chemical results, while handling very small quantities of material. Thus, either the worker who synthesises a minute amount of a complex organic substance, or he who sends up a chemical analysis of the same material, can lay equal claim to the title, and this, surely, regardless of the methods which he employs. In these columns we have consistently regarded the use of the polarograph or the spectrograph, as applied to problems of chemical analysis, just as much within our sphere as the qualitative analysis, by modifications of classical chemical separation, of an inorganic mixture. If we do otherwise, we immediately run the risk of condemning most modern analysis to banishment from the chemical circle. The Microchemistry Group and the Physical Methods Group must, in large part, deal with the same methods, albeit from different points of view. They are undoubtedly important to the latter as physical methods. They are just as important to the former in providing him with chemical results, that is, as microchemical methods.

Application of Micro Combustion Technique to Metallurgical Analysis

By G. Ingram

Problems associated with the application of micro combustion technique to the determination of carbon in steels are discussed. By elimination of the main sources of error it is possible to obtain results comparable with those obtained using standard procedures.

The apparatus necessary is quite simple.

A SEARCH through recent literature dealing with metallurgical analysis will show that most of the old and established methods of analysis are rapidly being replaced by micro techniques. This is due partly to the excellent instruments and apparatus available, and partly to the desire to obtain, in the shortest time, accurate analytical figures, a factor of the greatest importance to the metallurgist.

Micro combustion technique is regarded by many as a research tool, capable of success only in the hands of the specialist, where special cases merit its use; such as in investigations where only the minimum of material is available. A glance at one of the many relevant monographs published recently^{1,2} disproves this line of argument completely, accurate and precise analytical figures being readily obtained on micro samples of steels.

Of existing methods which have been described for the micro estimation of the constituents of steels little

information is given regarding methods for the determination of carbon or sulphur. This may be explained by the following considerations. With 5-10 milligram samples, the conversion of these two constituents into a form suitable for estimation is impractical, owing to the lack of accurate methods for determining the end products. For example, in the determination of carbon, combustion technique is invariably used to convert carbon into the dioxide which may then be determined by gravimetric or titrimetric methods. As the amount of carbon dioxide produced is small in relation to the amount of sample taken (for 1 gram samples 3.66-36.6 milligrams of CO₂) considerable caution is required in the subsequent treatment, more so when the amount of steel is reduced.

It must be clearly understood that these procedures, involving as they do the estimation of small amounts of elements, are micro methods using a sufficiently large quantity of sample that a result of the required accuracy is obtained. This applies more so to the sulphur determination, whereby with 1-gram samples the amount of sulphuric acid produced from the

1. N. Strafford. "The Detection and Determination of Small Amounts of Inorganic Substances by Colorimetric Methods." *Inst. of Chemistry*, 1933.
2. E. J. Vaughan. "The Use of the Spekker Photo-Electric Absorptiometer in Metallurgical Analysis." *Inst. of Chemistry*, 1941 and 1942.

combustion of steel is so minute that a micro burette is necessary to titrate the acid with any accuracy.

The following discussion is intended to clear the way ahead for a satisfactory solution of these problems.

To understand the problems involved in the micro determination of these two elements a brief résumé of existing analytical methods is necessary.

For carbon, such methods depend largely on combustion treatment with oxygen, with variation in procedure for determining the end product—carbon dioxide. Two other methods have been described, one chemical, and the other physical. The former consists of separation of the carbon by dissolution of the steel in potassium copper chloride,³ and subsequent filtration of the suspended carbon after centrifuging. The latter, for samples containing 0.5–1.1% carbon, makes use of magnetic saturation.⁴ It is obvious that application of these methods is impossible on reduced amounts of samples.

Sulphur is estimated by one of three methods. By combustion of the steel in oxygen, by the evolution method, or by dissolving the sample in an oxidising acid, with subsequent determination as barium sulphate. Of these methods, application to the micro scale has only been extended to the evolution method,⁵ due to the lack of means of estimating sulphuric acid from the combustion treatment on the one hand, and the impossibility of weighing such minute quantities of barium sulphate on the other. In fact, both elements require such special treatment in their estimation that the range of applicability at the present time lies only in the research laboratory and not as a general method for routine tests.

The Carbon Determination

As previously stated, combustion treatment is preferable for converting carbon into a suitable form for estimation, whether on the macro or micro scale. There are, however, several errors which must be taken into account, chief of these being the blank, which may exceed the actual carbon percentage of the sample determined. Wooten and Guldner⁶ have described a low-pressure combustion method in which it is stated this error, together with several others, is greatly reduced. With it an accuracy of $\pm 10\%$ has been obtained on 0.5 gram samples containing 0.003% carbon.

As this method has significant possibilities for future micro work a brief description is included now before discussing errors associated with high pressure combustion technique. The method consists of combustion of the steel, carried out in an all glass apparatus, with collection of carbon dioxide by condensation in a low temperature trap. The excess oxygen is pumped out and the amount of carbon dioxide determined by a pressure measurement, in a calibrated volume. The sample is heated by means of a high-frequency induction furnace, consisting of a refractory oxide crucible contained in a platinum crucible, suspended co-axially in a pyrex tubular chamber. The combustion chamber is connected with the necessary mercury cut-offs and low

temperature traps, a McLeod gauge being used to measure the difference in pressure. The system is evacuated by a high-vac. pump backed by a mercury diffusion pump. Oxygen for the combustion is highly purified by condensation in a liquid nitrogen trap and then passed over a palladium catalyst at 400° whence it is trapped and condensed in a further nitrogen trap, before admittance into the combustion chamber.

The sensitivity of the method is within 0.02 ml. of carbon dioxide or 0.02 micrograms of carbon. However, complete sensitivity is not obtained due to the small blank arising from the oxygen and apparatus. For further details of the method the original paper, together with one by Murray and Ashley⁷ should be consulted.

Errors of the Combustion Method

Errors associated with the combustion method are derived from three main sources. From the combustion of the sample, from impurities in the oxygen, and from the technique employed for the absorption and estimation of carbon dioxide.

The difficulty of oxidising quantitatively all carbon in the sample during the fusion period is well known particularly with ferrochrome steels. This fusion period is only maintained for a short time during the reaction of the sample with oxygen, excess of which is necessary to effect complete combustion. For this a rapid stream of the gas must be passed over the fused metal oxide formed, which, if too rapid, will introduce a further error in that incomplete absorption of carbon dioxide will occur. By reduction of the amount of sample taken, to 100 or even 10 milligrams, this error will be minimised by allowing a decrease in the flow rate of oxygen. Klinger, Kock, and Blaschczyk⁸, with 100 mgm. samples, use a slow stream of oxygen and pass the issuing gases from the combustion tube through a layer of copper oxide at 750° to effect complete oxidation of any carbon monoxide formed. One disadvantage of using such a slow stream is the fact that a much longer time is required for the analyses.

One other error affecting the accuracy of the method which seems to be largely overlooked is contamination of the metal sample with superficial dirt or grease. Gurry and Trigg⁸ recommend that the sample should be washed with purified acetone, the last traces being removed by suction in a vacuum desiccator. This process may be hastened by heating in vacuum in the usual drying pistol.

The second source of error, the presence of impurities in the oxygen supply is largely responsible for the blank, and may be traced to impurities arising by its passage through rubber tubing connections of the system. To eliminate this the oxygen should be passed over a platinum asbestos catalyst to oxidise carbonaceous material, which is removed by soda asbestos. Also all connections of the apparatus should be made by ground joints lubricated with phosphoric acid.

The method of absorption of carbon dioxide, the third source of error, is a critical factor in this determination. The method, being an empirical one, must always be checked by combustion of a standard sample of the same type as the unknown to be analysed. The blank must also be taken into account during the calculation.

Absorption may be carried out by wet or dry methods. In the latter Blumer absorption tubes containing soda

3. G. E. F. Lundell, J. F. Hoffman and M. A. Bright. "Chemical Analysis of Iron and Steel," p. 179, 1931.

4. B. A. Rogers, K. Wentzel and J. P. Rhot. *Trans. Amer. Soc. Metals*, 1941, **29**, 969.

5. P. Klinger, W. Kock and G. Blaschczyk. *Angewandte Chemie*, 1940, **53**, 537.

6. L. A. Wooten and W. G. Guldner. *Ind. Eng. Chem., Anal. Ed.*, 1942, **14**, 535.

7. W. M. Murray and S. E. Q. Ashley. *Ibid.*, 1944, **16**, 342.

8. R. W. Gurry and H. Trigg. *Ibid.*, 1944, **16**, 248.

asbestos are used with advantage, because of the ground-in stoppers which will exclude the necessity for sweeping out with air before weighing, and hence will shorten the time required for the analysis. Further, all weighings should be carried out on a micro balance to ensure the utmost accuracy.

The wet absorption method consists of passing the exit gases through baryta solution and weighing as barium carbonate, using the Niederl-Meadow⁹ absorption attachment. Alternately, the carbonate may be converted to sulphate and weighed as such. On the micro scale standard baryta¹⁰ is used, the excess being titrated with standard potassium hydrogen phthalate.¹¹

Of these two methods the wet absorption one is more advantageous when using 10-50 milligram samples

One such apparatus is shown in Fig. 1. The furnace (a) can be easily constructed in the laboratory from a 20 cm. length of porcelain tube of a slightly wider diameter than that of the combustion tube. One half is wound with platinum wire, and the other with nichrome wire of sufficient resistance to procure a temperature of 450°. The heating element is covered with alundum cement and encased in a lagged heat-resisting cover fitted with end plates protected by asbestos board at least 1 cm. in thickness.

The purification system (b) consists of a flowmeter connected by a ground joint to the quartz preheater (c), containing the catalyst. This in turn connects via a B.14 joint to a U-tube containing anhydrous, and to a further tube containing equal lengths of soda asbestos and anhydrous. Connection to the combustion tube is made with a B.10 joint. When using the gravimetric method of absorption the oxygen supply must be moisture free. Hence the filling of anhydrous.

The choice of combustion tube depends on the temperature required for the various steels and alloys. For normal steels a quartz tube can be used successfully at temperatures between 1000-1200°. However, for alloys which require much higher temperatures, porcelain tubes must be used, as quartz will not withstand the high temperatures involved, for any length of time.

The use of porcelain tubes does not impair in any way the applicability of the method, as combustion tubes are now obtainable fitted with a side arm for introduction of oxygen, and a tapered end for connection of the absorption apparatus with rubber tubing. This does away with the troublesome bung as used in most macro

containing less than 0.5% carbon. The carbon dioxide, too small in amount to be weighed on the micro balance, can be converted into a heavier form such as barium sulphate, which is suitable for weighing. However, one disadvantage in connection with the use of baryta solution is that every precaution must be taken to avoid contamination by atmospheric carbon dioxide. The absorbent solution should be filtered directly through a sintered glass filter into the absorption vessel to remove traces of suspended barium carbonate.

In conclusion, complete removal of sulphur is necessary in the high-pressure combustion method. This is usually accomplished by the addition of a chromic-sulphuric acid mixture between the absorption apparatus and the combustion tube. This arrangement can be simplified by replacing the acid mixture by a plug of silver wool inserted at the exit end of the tube, maintained at a temperature of 450°. In the low-pressure method sulphur dioxide does not interfere in any way with the results, being removed partly by the refractory crucible now used, the remainder being trapped in one of the traps at -80° placed after the combustion chamber.

Combustion Apparatus

Apparatus for this method is comparatively simple, consisting of a platinum wound furnace, purification system, combustion tube and absorption apparatus.

9. Niederl-Meadow. *Mikrochem.*, 1951, **9**, 350.

10. M. H. Kalina and T. L. Joseph. *Heat Treat. For.*, 1930, **25**, 16c.

11. A. Lassieur. *Compt. rend.*, 1938, **207**, 731.

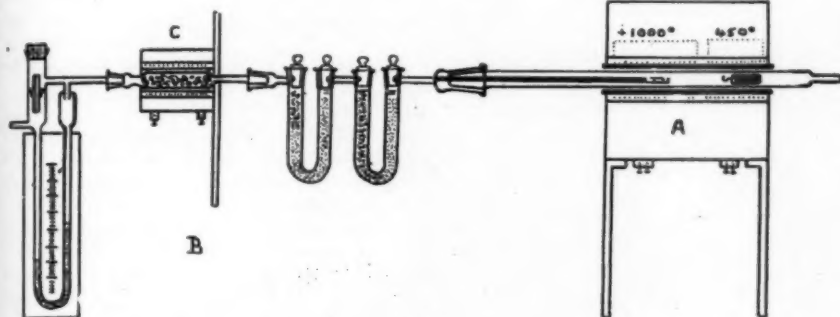


Fig. 1.—Combustion apparatus.

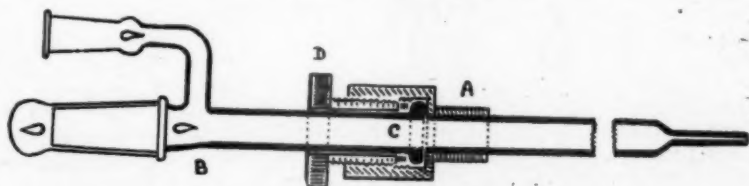


Fig. 2.—Quartz adapter.

methods which provided a further source of error. With porcelain tubes, so that rubber connections are avoided as far as possible before the absorption system, the attachment shown in Fig. 2 has been devised, making possible connection between the combustion tube and purification system by a ground joint. Also, the open end of the tube used for the introduction of the sample may be closed by a ground joint.

The wide end of a porcelain tube is pushed into the metal holder at (a) and sealed with a suitable heat-resisting cement. The quartz adapter (b) consisting of the side arm to which is attached a B.10 female joint, and B.14 ground joint stopper, is fitted into the

wider end of the metal holder so that the flange (c) fits flush with the end of the porcelain tube. The threaded nut (d) is then screwed down on the flange so that a rigid tight fit is obtained. The quartz flange, which is ground flat, is protected from the nut by an asbestos washer 2 mm. in thickness.

The sample is introduced into the combustion tube by a quartz scoop attached to the inside of the ground stopper by a rod, so that when the combustion tube is

closed, it is in the centre of the hottest zone of the furnace. (See Fig. 1.) Space will not allow for further details involved in the determination, which may be found in most treatises on the subject. However, it is hoped that this short article outlining the principles and hazards appertaining to the method will give a clearer picture of the problems arising from application to the micro scale. The second part of this article will deal with application of the micro combustion method for sulphur. (To be continued.)

An Elevating Table for Use in Microtitrations, etc.

G. H. Wyatt.

IN most modern procedures for microtitration the burette is so constructed that delivery occurs when the jet is immersed in the liquid being titrated and ceases when the jet is withdrawn—see, for example, Wyatt*. In this way the end-point may be attained without the error inherent in the delivery of discrete drops of appreciable size, as occurs when delivery is from a jet surrounded by air. The burette may be so mounted that it may be raised or lowered, but it is usually more convenient to place the titration vessel on a table the height of which may be adjusted; moreover, such an elevating stand has general usefulness in the laboratory.

The apparatus shown in vertical section in the accompanying Fig. was made of brass. The rising and falling pillar A carries a square table B, located by a locking nut C; these may be replaced in special cases by a suitable clamp screwed to the top of the pillar. Vertical motion is attained on turning the knurled ring D (pitch of thread = $\frac{1}{16}$ in.), which is secured from leaving its seating by the grub-screw F engaging a slot in the lower part of D. Rotation of the table during its vertical travel is prevented by the grub-screw G, the end of which fits in a vertical slot in A; the length of this slot determines the limits of motion of the table. The whole is mounted on a square base H. (A horizontal section XY is also drawn to the same scale.) In the author's model, which has the dimensions shown in the Fig. the table travels from

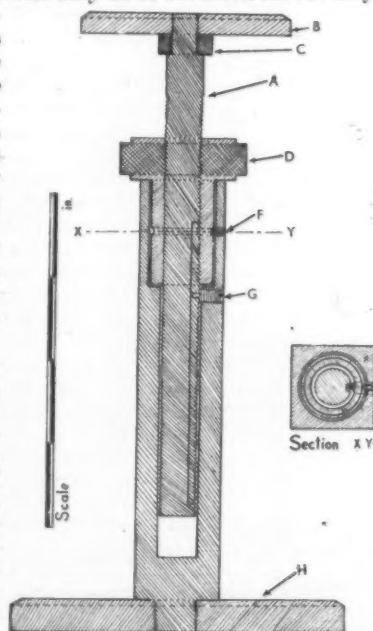


Fig. 1.—Elevating table.

* G. H. Wyatt, *Analyst*, 1944, 69, 81, 180.

7 in. to 10 in. above the bench level; alterations may obviously be made to suit individual requirements.

Spectrographic Analysis

RECENTLY the editorial committee of *Industrial and Engineering Chemistry (Analytical Edition)* has decided that there is a need for papers which will enable analysts to keep abreast of new developments in analytical chemistry, and will permit them to assess not only the advantages, but also the limitations of the newer methods. Introducing this new viewpoint, they have published a series of three papers which cover the field of emission spectrographic analysis.

The first of these papers¹ discusses the techniques of quantitative spectrography. Various methods of exciting the spectrum, including the direct current arc, the alternating current arc, and the alternating current spark, with some reference to units which enable any one or a combination of these to be used, are detailed. The nature of a satisfactory spectrograph is outlined. Photographic operations and the method of photometry of the photographed spectrum are dealt with. The article concludes with a detailed critical discussion of various methods used for calibration and the final calculation of results.

The second article² defines in some detail the qualifications which must be possessed by the spectrograph, the microphotometer and the excitation equipment which is to be used for quantitative work, if it is to be considered satisfactory. The specifications are drawn up with an eye to the demands both of the analyst and of the apparatus manufacturer. A draft specification is appended, which includes the essential requirements laid down by the writer.

Finally, the third paper³ gives the details of a satisfactory method of qualitative analysis which will also enable the analyst to arrive at a satisfactory semi-quantitative estimation of the elements present by comparison with a series of standards. A valuable table of line interferences is included, together with notes in tabular form of the sensitivities and sensitive lines of the elements which can be included in such an analysis, fifty-three in number.

The writer points out that such a qualitative examination may be very valuable as a guide to quantitative chemical analysis, as an aid to X-Ray analysis, or as an indication of the presence of trace elements in both raw materials and in finished products.

¹ J. R. Churchill, *Ind. Eng. Chem., Anal. Ed.*, 1944, 16, 653.

² C. L. Guettel, *Ibid.*, 670.

³ G. W. Standen, *Ibid.*, 675.

Light Metal Permanent Mould Castings (A Composite)

THE remarkable service which light-metal castings have provided the various war applications can be attributed in no small way to the development and improvement of the permanent mould casting process. The advantages and characteristics of such castings have been discussed recently in two interesting and practical papers. In the first, L. F. Swoboda¹ deals with aluminium and magnesium alloys in the form of permanent mould castings, and in the second, J. Vickers² discusses the production of aluminium alloy permanent mould castings for liquid-cooled aero engines.

The process of permanent mould casting consists of pouring molten metal into a hot mould or die, and differs from the die-casting process in that the metal is fed into a hot mould cavity by the force of gravity rather than into a water-cooled die by pressure. A variation of the permanent mould process, known as the semi-permanent mould method, consists of using a dry sand core for the interior surfaces and a metal mould for the exterior surfaces. The semi-permanent mould method is used when it is impossible to remove steel and iron cores from the interior of the finished casting, and when a smoother surface is required on the exterior than

could be obtained if the part were made as a sand casting. The properties of some light metal permanent mould alloys are given in Table I.

In permanent mould casting, if metal is correctly poured into a properly designed mould, solidification takes place progressively, and it is this progressive feeding of the casting, together with the rapid chill the metal receives on coming into contact with the metal mould, that produces a dense fine-grained structure, the mechanical properties of which are substantially higher than those obtained in other type castings. The physical properties are also enhanced by the fact that well designed permanent mould castings are unusually free from the more common foundry defects, such as inclusions and porosity. The amount of finish necessary for machining may therefore be reduced below that required for sand castings,

and, since the essential surfaces of castings can be made smooth, finishing operations may be eliminated for many purposes. As the result of the smoothness and accuracy possible with the permanent mould process, many holes can be cored to size and this machine operation eliminated.

Swoboda also states that one of the chief requirements in the design of permanent mould castings is to allow for the withdrawal of cores from the casting and the removal of the casting itself from the mould. Split core, multiple piece moulds or sand cores may be used, however, for castings on an inherent design which cannot be changed sufficiently to permit the use of a solid core. When castings are being designed to facilitate production, the number of mould parts should be as small as possible, a minimum number of cores should be used, and to minimise maintenance cost, extremely long cores should be avoided whenever possible. Where inserts of other metals are cast in light-alloy permanent mould castings, a definite foundry technique is required, since light alloys have different coefficients

TABLE II.—COMPRESSION OF PERMANENT MOULD DIE CASTINGS AND SAND CASTINGS.

Casting.	Gear Case Cover		Coolant Pump		Boost Control Casting		Rocker Cover Casting		Cover Plate and Guide Casting	
Type.	Sand Cast	Die Cast	Sand Cast	Die Cast	Sand Cast	Die Cast	Sand Cast	Die Cast	Sand Cast	Die Cast
Bonus Time Allowance min.	165	40	171.0	81.75	125.5	35.0	264	93.5	66	44.75
Finished Casting Weight, lb.	14	12½	5.015	4.63	3.928	3.687	12.75	9.687	1.875	1.706
Labour Cost per Casting	4/-	1/1	2/5	8½d.	2/5	8d.	5/0	1/0	1/7	8d.

1. *The Foundry*, 1945. Vol. 72, No. 1, pp. 72-74, 176, 180, 182, 184.

TABLE I.—PROPERTIES OF SOME LIGHT METAL PERMANENT MOULD ALLOYS.

Alloy (Alcoa Numbers)	Yield-Strength (Set 0.2%) lb. per sq. in.	Ultimate Strength lb. per sq. in.	Elongation 2-in.	Brinell Hardness 500 k.g. 10 mm.
43	9,000	24,000	9.0	45
B 113	19,000	28,000	2.0	70
C 113	28,000	30,000	1.0	80
A 152-T 551	28,000	36,000	0.5	105
138	24,000	28,000	0.5	100
B 195-T 6	33,000	45,000	7.0	90
A 214	16,000	27,000	5.0	60
355-T 6	27,000	43,000	4.0	90
AM 240-T 6	16,000	35,000	4.0	60
AM 260-T 6	20,000	38,000	3.0	78

of expansion from other metals. Wherever practicable, uniform sections should be maintained throughout a permanent mould casting, since section uniformity helps not only to simplify the gating and feeding problem, but also to equalise the rate of solidification. The minimum section thickness possible in light-alloy permanent mould castings depends on the size, pressure requirements and intricacy of the casting, but, in general, the minimum section thickness which can be cast in permanent moulds is approximately $\frac{1}{8}$ in.

In his paper, Vickers² deals with aluminium alloy castings produced as gravity die or permanent mould castings and states that with such castings a smoother finish and closer dimensional accuracy is obtained, castings have improved mechanical properties, and that there is greater speed of production, conservation of raw material and a reduction of production scrap. In designing such castings it is necessary to determine the gating system, together with the position of the die-parting, the location and direction of extraction of cores, the method of release of the casting from the die, and general die shape and thickness, etc. The use of sand cores is discouraged, principally because with such cores a certain degree of accuracy is lost through core location, and also because the presence of an oil sand core results in the generation of core gases during casting.

When a die is fully assembled it should be fully tested in an experimental die foundry and the most suitable technique such as die coating and its application, pouring temperature of alloy, die temperature, method of pouring and production time cycle established and recorded for use of the production foundry. A sample casting or castings should be checked for dimensional accuracy, and a radiological examination carried out to ascertain that faults not visible to the eye, such as internal porosity, shrinkage, blow-holes, etc., are not present, thereby confirming that the gating system and general production technique for the die is satisfactory.

Permanent mould castings produced for the Merlin engine include gear case covers, coolant pumps, boost control castings, rockers, covers and cover plate and guide castings. Comparative data for the producing of such castings are given in Table II. The designing of such castings is discussed in detail with special reference to gating and venting, the number and location of cores and the pouring of the metal. In some cases, as with rocker cover castings, bottom pouring is absolutely essential because of the intricacy of the die cavity and the metal is directed down an inclined runner and through a ring runner into the bottom of the casting.

Permanent mould gravity die casting has also been used successfully for producing cylinder skirt castings measuring 3½ feet in length and weighing 53 lb. for aero-engines. In such a size of job, the prevention of

base cracking on the outside due to the bursting stresses set up when the centre becomes heated to a higher temperature than the outside with consequent greater expansion is overcome by heating all sections of the die uniformly initially and maintaining

the die in that condition. To overcome problems inherent with unequal expansion due to varying degrees of heat, each main die half has to be built up in three layers. A similar principle is also included in top blocks forming the feeding heads.

Skin Recovery for Decarburised Steel Surfaces

By O. E. Cullen

SURFACE decarburisation of carbon and low-alloy steels have always been a source of trouble and worry to the steel manufacturer and, in a much greater degree, to the machine designer and metal user. Removal of decarburised areas by mechanical means is one method of raising the endurance limit of the steel, and applying compressive strength to the decarburised surfaces by peening or shot blasting is another helpful treatment. In the former case, proper dimensional allowances must be made

substantially neutral, with no carburisation taking place, but that, unfortunately, previous heating operations had caused decarburisation of the surface layers and this condition could not be removed by the final treatment. The development of the skin recovery process presented problems which had not been encountered in normal carburising practice. Basically, carburising is a treatment for establishing a definite carbon gradient from the steel surface to the lower carbon metal some distance below the surface. A carburising potential or unbalanced carbon pressure must be maintained between the atmosphere and the original steel, if carburising is to continue. Skin recovery on the other hand seeks to eliminate an already established inverse carbon gradient and its success is predicted upon setting up an exact carbon pressure between the atmosphere and the original carbon in the steel. In carburising, depth of penetration is a function of time and temperature, while in skin recovery carbon penetration at any particular point ceases when a carbon balance is reached between atmosphere and steel, and, thereafter, time has no effect.

In view of the problem involved, it was apparent that gas carburising atmospheres, with some few changes, should be suitable for skin recovery. By experimenting, it was found that carbon dioxide and water vapour (both undesirable in regular carburising) do assume positions of importance in the skin recovery process. Methane of the other hydrocarbons ceases to be as vital and must be held to a minimum if the best carbon balances are to be maintained. Optimum gaseous mixtures vary with temperature and carbon pressure, but the ratios of CO₂, CO, H₂ and H₂O, once established for a given temperature, will give an unchanging carbon pressure with readily reproducible results. It is imperative, however, that the gas be prepared in a suitable type of gas

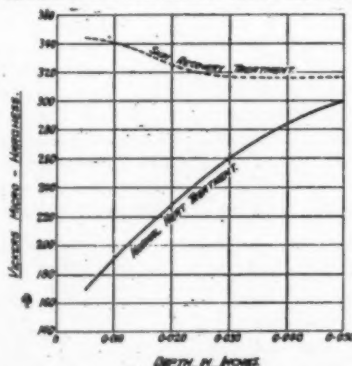


Fig. 1.—Hardness (Vickers) depth readings of S.A.E. 4140 steel forgings before and after skin recovery.

to take care of the maximum decarburisation which may occur and this is sometimes difficult to predict. These treatments have also their distinct limitations. One of these is the inaccessibility of some surfaces to mechanical operations. Another method of surface treatment comprises restoring carbon to the depleted surfaces by a newly developed process. This involves heat-treatment in a controlled atmosphere which is so regulated so as to bring about the desired results. This process is known as "Skin Recovery."

Investigations proved that in many cases final heat-treatments were being carried out in atmospheres which were

2. *The Foundry*, 1943, Vol. 72, No. 2, pp. 86-87, 200, 202, 204, and No. 3, 100-102, 200, 202, 204.

Metals and Alloys, 1944, Vol. 20, No. 4, pp. 954-958.

generating unit, since it is subject to such close limits of control.

Various types of decarburized carbon and low-alloy steels have been subjected to skin recovery treatment and the results obtained have been uniformly successful. The benefits of the treatment are emphasized in Fig. 1, showing graphs of Vickers micro-hardness readings taken at various points from surface to core of fully heat-treated S.A.E. 4140 steel forgings

with and without benefit of skin recovery. To date there is no evidence that carbon balance between the atmosphere and the carbon in the steel is affected by other alloying elements which may be present.

The skin recovery treatment is adaptable for use with either batch type or continuous furnaces. Forgings receiving the treatment have shown no signs of failure due to surface conditions.

Mounting and Electropolishing of Micro-Specimens

By U. J. Hochschild

THE development of the metalurgical microscope and other apparatus and material used in conjunction with it, have made great advances in recent years. Among those are better photomicrographic plates improved illumination sources, improvements of optical design, advances made in the use of polarized light, better mounting methods and new polishing technique. The last two operations by which a flat surface is obtained do not present any great difficulties when specimens are large enough to be handled comfortably, but with small specimens, obtaining a flat surface without any rounding-off on the edges, becomes practically impossible quite apart from the difficulties encountered in holding small specimens against a grinding or polishing wheel revolving at high speed.

To solve the above-mentioned problems it is modern practice to embed metallographic specimens in some plastic material, which, when duly processed, becomes hard and impervious to chemical solutions used in etching. The plastic used may be opaque or transparent and the most popular method is that of mounting with the aid of a hydraulic press. This method of mounting not only eliminates the difficulties mentioned but several specimens may be mounted together in one mount. One difficulty, however, remains, and that is keeping small specimens, such as pieces of wire, in their proper position during mounting.

To overcome this difficulty, a new mounting technique¹ has been developed and used successfully for mounting specimens intended for mechanical polishing. This new method is based on the fact that a thermosetting material, such as bakelite, once treated

retains its hardness and shape when subjected to a second heating. A disc of such thermosetting material, about $\frac{1}{4}$ to $\frac{1}{2}$ in. thick, is made in the mounting press in the usual manner, and this disc is drilled with holes slightly larger in diameter and shape than the specimens under examination, and serves as a holder for them. This holder with its specimens is then placed on to the bottom plate of the mould assembly and treated in the same way as in making a simple mount when the specimens are sealed tightly into their respective holes by the melting and subsequently hardening mounting powder used in building-up the completed mount.

Electropolishing removes from a specimen surface the worked metal layer resulting from grinding and buffing, without etching the specimen, by placing the specimen as an anode into a suitable electrolytic cell. Various constructions of apparatus and electrolytes have been devised and found suitable for electropolishing. When polishing large mounted specimens, electrical contact is made by a platinum wire which under light spring tension touches a corner of the specimen surface. With small specimens, such as pieces of wire, this method has its limitations, since the cross-section of such samples is much too small and only one specimen at a time can be connected. This problem has been solved by mounting an additional wire along with the specimen to be polished and connecting it electrically, inside the mount, to all specimens in order to serve as a mutual conductor to furnish contact with the platinum wire in the electropolishing apparatus.

A method to establish electrical connection between all the specimens in the mount is to embed them in a copper powder compact in the manner

previously described, using copper powder instead of plastic mounting powder. Mixtures of copper powder and plastic material have also been used. These methods, however, wherein copper powder compact is exposed to the electrolyte, have certain disadvantages. Compared with the small surface area of the specimens the surface of the copper powder compact is very large, making it difficult to control current density on the surfaces to be polished. Within a short time the electrolyte destroys the copper powder part of the mount, due to electrolytic dissolution aided by the porosity of the compact, and the destruction continues on storing the mount. The greatly increased flow of current passing through the electrolytic cell during electropolishing leads to a higher evolution rate of hydrogen gas at the cathode, causing some agitation of the electrolyte.

A new method² which overcomes these disadvantages is to prepare a small cup of a thermosetting plastic material by means of a suitable die. This cup which serves both as a specimen holder and container for a copper powder compact is placed on the bottom plate of the mould assembly, the specimens together with the wire which later is to furnish electrical contact with the platinum wire in the electropolishing apparatus, are inserted, a small layer of either thermoplastic or thermosetting mounting powder is placed into the bottom of the cup to seal the fine spaces between the specimen and the holder, and a layer of copper powder filled into the cup almost to capacity. After placing the mould cylinder over the whole assembly, either opaque and thermosetting or transparent and thermoplastic mounting powder is added to the desired height. In the beginning only a light pressure of 500 lb. per sq. in. is applied in order to leave the copper powder in a flexible condition. A heavier pressure of 4,000 lb. per sq. in. is applied only after the melting point of the plastic is reached and is transmitted through the mount compacting both layers of plastic and copper powder simultaneously. With this method of mounting, the copper powder compact being enclosed cannot interfere with electric current control during polishing, and it is completely protected from any sort of corrosion, thus assuring a permanent electric contact inside the mount.

1. *Metals and Alloys*, 1944, Vol. 20, No. 6, pp. 1614-1616.

2. *Metals and Alloys*, 1945, Vol. 21, No. 2, pp. 409-412.

Quenching of Magnesium Alloys to Secure High Yield and Good Ductility

By R. S. Busk and R. E. Anderson

IN a study on water quenching of some typical magnesium casting alloys, the authors found that the rate of cooling of commercial magnesium-base casting alloys from the solution heat-treated state affected the properties obtained upon subsequent precipitation. Improvement in mechanical properties is effected in all the alloys considered by increasing the rate of cooling. The improvement obtained was found greatest for C alloy (9% Al, 2% Zn and 0.2% Mn) and least for R alloy (9% Al, 0.7% Zn and 0.2% Mn). By quenching the castings before aging, the tensile properties of metal in complicated production castings are improved at least 10% and even considerably more under the most favourable conditions.

In general, the rate of cooling produced by hot water quenching C alloy is beneficial to the properties not only of separately cast sound test bars but also of the casting sections themselves. The most noteworthy improvement is in the combination of high yield strength with good ductility. This is especially evident with low temperature short-time ageing after the solution heat-treating and quenching. The improvements in physical properties are all gained without introducing significant locked-up stresses in the casting. Thus full design benefit can be taken from the increased property values. Since the endurance limit is not greatly raised by quenching and aging, this process is of practical importance in those cases where high strength is important, and where better fatigue properties at low cycles are necessary.

When a complicated casting is suddenly chilled, different cooling rates are produced in the various sections. This gives rise to stresses, due to differential contraction, which may result in residual stresses, warping or cracks. Qualitative observations during the sawing of quenched castings have indicated the presence of only low residual stresses. Extensive relaxation studies show that there is rapid relief of stress during precipitation treatments. Thus heat-treated, quenched and aged magnesium castings will have very small if any residual stresses. There is a direct relation

between the rate of cooling and the improvement of mechanical properties.

Since ideal castings are seldom attained, tests were made to discover the effects of each defect on the quenched and aged properties. Some special test bars were made in such a manner as to produce porosity in the reduced section. These were heat-treated, water quenched and aged, then radiographed and the porosity rated. Although results were quite

erratic, the strength of the quenched bar was always higher than an air-cooled bar with a similar amount of porosity. With considerable porosity present, the tensile strength of the quenched and aged C alloy was 10% better than that of the air-cooled and aged bar. The fatigue strength of porous C alloy after quenching and aging was compared to air cooling and aging. If any porosity visible in a radiograph of the specimen were present, no improvement due to quenching was detectable. Thus improvement in the fatigue strength can be effected by quenching only when the material is sound and even then the improvement is small.

Fractography—A New Tool for Metallurgical Research

By C. A. Zapffe and M. Clogg

FRACTOGRAPHY is the name applied to a newly developed technique of studying untouched cleavage facets at high magnification. As a supplementary metallurgical tool, fractography by definition offers many of the advantages of single crystal methods, since the field is oriented about the cleavage plane; the field is nascent and untouched and, therefore, and, therefore, reveals much of the internal structure of the grain which cannot be seen after polishing and etching; the plane of weakness, which is often the plane of greatest interest, becomes *ipso facto* the plane of observation; time may be saved by avoiding mounting, polishing and etching; and tiny chips and otherwise unusable fragments are suitable for fractographic examination.

The experimental technique is very simple, requiring only three accomplishments: (1) Obtaining a brittle fracture; (2) Orienting a facet with the axis of the microscope; (3) obtaining the close approach of the lens to the specimen required for high magnifications. As regards obtaining a brittle fracture, because each cleavage facet constitutes a specimen, the metal is made to break in such a manner that an individual facet covers most of the microscopic field at the magnification desired. Brittle metals generally conform to this without pre-treatment, except for some which cleave irregularly or conchordally. For normal ductile metals, sufficient

brittleness can often be conferred by rapid fracture, as by impact; by fracture at subnormal temperatures; by embrittlement with cathodic hydrogen; or by other means, such as by hydrostatic rupture. Any fractured face will usually serve, whether it is that of a standard tensile specimen, a failed part, or a mere chip from a sample.

In orienting one or several of the individual cleavage facets perpendicular to the axis of the microscope, a preliminary low-power examination will aid in selecting the best facet. To accomplish the orienting, a simple orienting mechanism is used, consisting of a base-plate, which fits into the annular opening in the stage of the microscope, and a superimposed specimen holder supported by three screws, whose bases are countersunk slightly into the base-plate. The specimen is held from above by any suitable means, such as clamps, bakelite or plastic in the central holder, with the faces of the specimen approximately horizontal. Starting with a low-power objective, a given facet is brought into approximate horizontality by means of the three levelling screws.

To obtain the close approach of the lens to the specimen required for high magnifications, surface irregularities have to be removed. Using an electrical hand-grinder, while observing the specimen under a low-power, grinding operations on interfering promontories can be performed sufficiently delicately to allow the use of a contact objective

on almost any specimen. A variety of tips can be obtained for such an instrument, allowing for grinding, drilling or buffing, the latter operation being used for applying a polish-etch technique to individual cleavage structures. A long-nosed objective lens is suitable for such work.

Materials studied by the new method of examination included Armco ingot iron, stainless steels, silicon ferrites containing from 1.59% to 78.26% silicon, antimony, bismuth and rock salt. The appearance of grains and grain boundaries in fractographic specimens are found to be different from those in most polished and etched specimens. The change in the cleavage direction because of the different orientation of contiguous grains gives a ridge-like effect, the secondary grain being in shadow and generally proceeding out of focus away from the boundary of the focused facet. Although metals are distinguished as a class by their unique deformability, when fractured in a brittle manner,

they often show informative similarities with non-metallic crystals. Ingot iron shows well-developed crystallographic markings on its fracture which are not unlike those shown by rock salt. Fractured bismuth showed at least four separate structures, some known and some unknown.

In the determination of constitution phases could usually be recognised on a fractograph as conveniently as on a polished and etched specimen, for the fracture type of a phase was as distinctive as its etch type. It was also shown by the examination of a stainless steel and a silicon ferrite that new structures and new facts about known structures might be developed by the use of fractography, since well-known microconstituents showed new structures on a fracture. The use of fractography as a research method also had interesting aspects, as cleavage facets at high magnification, 2000 and over, suggested many examples which might be investigated.

averaging 2,060 kg./cm.²). However, in view of the inherent microscopic irregularities of fit at brazing interfaces, and the physical nature of the cementation process involved in brazing, it is questionable to attribute the above increases in shear strength entirely, if at all, to the change in specimen design from a central tube to a central plug.

Determination of Columbium in Steel

By John H. Vail

A RAPID method for the determination of columbium* in steel is given. As a 0.5 gm. sample is generally used to determine chromium and nickel in this material, it is speedy and convenient to analyse this same sample for silicon and columbium although more accurate work would require a larger sample. Accordingly, weigh out a 0.5 gm. sample into a 250 cc. beaker. Add 25 cc. of hydrochloric acid (1:1) and heat until the initial reaction is complete. Add 10-15 cc. of 60 or 70% perchloric acid and heat to strong fumes. Heat until all the chromium is in the form of chromic acid and the residue is a bright orange red. Remove from the hot plate, cool and dilute to about 200 cc. with water. Boil for several minutes to remove any chlorine. Again remove from the heat and filter through a No. 42 Whatman filter paper, reserving the filtrate in a 600 cc. beaker. Wash several times with hot water. Remove the beaker and reserve for the determination of chromium and nickel. Wash the precipitate and paper with hot 5% hydrochloric acid and hot water until clean. This precipitate of columbium pentoxide and silica is placed in a tared platinum crucible and cautiously ignited at 1,390° F. (755° C.). The crucible is cooled and weighed. The residue is moistened with a few drops of concentrated sulphuric acid and about 5 cc. of 48% hydrofluoric acid. The crucible is heated on the hot plate to the absence of fumes and again cautiously ignited at 1,390° F. (755° C.).

The crucible and its contents are cooled to room temperature and the residue washed into a 250 cc. beaker with 100 cc. of 5% hydrochloric acid. Add 30 cc. of saturated sulphurous acid. Boil on the hot plate for 5 min. and filter through a No. 42 Whatman filter paper, after digesting with paper pulp for a few moments. Wash the

Chemical Industries, January, 1945. (*for niobium)

Shear Strength of Copper-Brazed Joints

By N. L. King

WHETHER or not the degree of surface finish of the brazing interfaces has any influence on the resulting joint was the object of a test recently terminated in the engineering test laboratories of the Consolidated Vultee Aircraft Corp'n. Differences in joint strengths were not sufficiently large or in the direction to warrant conclusions concerning the influence of the surface finish factor. The test specimens were copper-brazed units made up of a barrel member, and a ring drive-fitted over it. The 53 specimens comprised four groups of samples whose interferences or negative clearances (difference between ring diameter and barrel diameter) ranged from 0.001 to 0.0018 in. (0.025 to 0.046 mm.). Each group of specimens was identified by the symbols D, E, F and G, representing the fineness of the surface finish of the machined barrels and their corresponding rings. Specimens with the symbol D had the finest finish and each following group was about twice as rough as the preceding group. The surface finishes of the specimens used in this test were reproduced in accordance with reference samples furnished by General Electric Co. The degree of surface roughness on these references is measured in micro-inches (millionths

of an inch) and represents the average deviation from a centre line on a profile contour of the surface. The D samples had a surface finish of 32 micro-inches (0.00081 mm.), and G samples one of 250 micro-inches (0.0064 mm.).

All specimens were tested in shear in a 200,000 lb./sq. in. (14,000 kg./cm.²) Southwark-Emery testing machine. In general, the average shear values of the test specimens with the four different finishes, D to G inclusive, varied only slightly. However, the E series, which had the second finest finish, was slightly lower in shear strength. In all cases the shear strength was found to be in excess of 23,000 lb. per sq. in. (1,600 kg./cm.²).

Because of the somewhat lower shear strength values obtained on the group of specimens of surface finish E than on the other three groups, a second test was made as a check, with the substitution of a central solid cylinder in place of a tube. As in the previous test the interference was approximately 0.001 in. (0.025 mm.). Values of shear strengths obtained on these specimens ranged from 32,200 to 50,700, averaging 41,400 lb. per sq. in. (2,260 to 3,560, averaging 2,910 kg./cm.²), as against the previous range of 23,700 to 35,000, averaging 29,300 lb. per sq. in. (1,670 to 2,460,

The Iron Age, March 8, 1945.

paper and its contents with 5% hydrochloric acid and hot water until thoroughly washed. Place in the platinum crucible and ignite at 1,600° F. (870° C.). Cool and weigh the columbium precipitate as the oxide. The difference between the two weighings measures the silica. The filtrate from the first filtration is used for the determination of chromium and nickel. It is diluted to 500 cc. in a volumetric

flask. A 100 cc. aliquot is taken for the determination of chromium by titration with ferrous ammonium sulphate and potassium permanganate. A second 100 cc. aliquot is used for the precipitation of nickel by dimethylglyoxime. Duplicate analyses of columbium-bearing stainless steels give good agreement, when analyzed by the proposed and similar methods.

Micro-Deformation under Tension and Compression Loads of Thin Aluminium Sheets

By G. Welter

IN view of the importance of the anisotropy (direction of rolling) of the sheets and their elastic stability in connection with economic use of the material in aircraft, special consideration was given to elastic characteristics, such as Young's modulus of elasticity, as well as the micro-elastic and micro-plastic properties of aluminium alloy sheets for aircraft construction. The usual properties of yield strength, ultimate strength and elongation were also measured. Three sheets (designated D, A, and B) were tested at (1) seven different angles to the direction of rolling and cold stretching, (2) over the whole width of the sheets, and (3) over a distance from about 8 to 25 in. in the direction of rolling. In making the tests for the determination of the values of main directional properties, at least two and up to ten identical tests were conducted.

Besides tensile tests such as are generally used in this type of investigation, a more delicate study of the behaviour of thin sheets under compressive loads was undertaken, as such tests seemed necessary for a complete understanding of the mechanical properties of the material in connection with its practical application in stressed skin constructions. An investigation of successive stresses, as tension succeeded by compression and vice-versa also showed interesting results which cannot be neglected in the design and construction of modern monocoque structures operating under similar conditions.

Thin sheets, 0.032 in. thick, of aluminium alloy 17 S-T. (duralumin) of the nominal composition 4% copper, and cold-stretched were used for the

main tests. These were (1) the determination of anisotropy and directional characteristics under tension and compression, measuring Young's modulus of elasticity, the elastic limit with 0.001% micro-deformation, the stresses at 0.001 and 0.1% permanent set, the yield strength (0.2% set) and the tensile strength and elongation parallel, transverse, and at 15, 30, 45, 60 and 75 deg. to the direction of rolling; and (2) Bauschinger-effect and micro-plastic deformation in tension and compression, observed in single test specimens. From each test specimen a micro- and a macro-load deformation was recorded during the test and from these diagrams the modulus of elasticity, stresses at permanent deformation, and yield strength were calculated. Stresses under compressive load were calculated in the same manner. A new kind of tension grips and new devices for guiding specimens axially in compression were used and found satisfactory for measuring micro-deformations in tension and compression.

The various tests show that all mechanical properties of 17 S-T rolled aluminium alloy sheets depend on the angle between the test specimen and the direction of rolling, and in all cases a minimum of 4 to 5% less ultimate resistance was noted in the direction of 30 to 60 deg. compared with the direction of rolling. The yield strength 0.5% manganese, 0.5% magnesium, and balance aluminium, heat-treated (0.2% set) was highly dependent on the angle of the specimen with the rolling direction of the sheet, and a greater influence was found in all cases for the 0.1% limit, showing up to 20% less resistance in the 75 to 90 deg. direction; for the yield point this difference was about 15%. The stresses

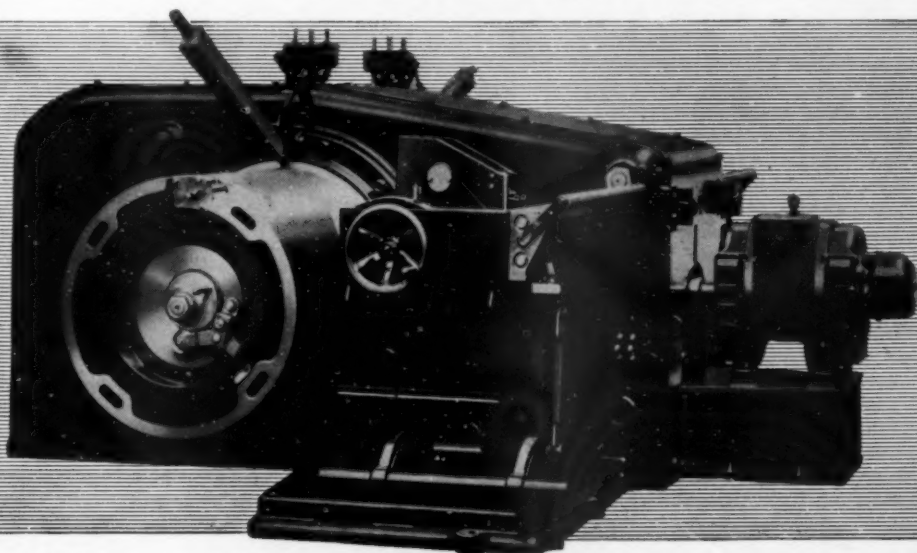
for a permanent micro-deformation of 0.01%, depending on the position of the specimen in the sheet, change in a rather impressive manner, more than 20% less resistance being measured for sheets D and A and up to 25% for sheet B between 0 and 60 deg. to the direction of rolling. The very pronounced directionality of these important mechanical properties for constructional purposes was primarily due to cold stretching or the levelling process during manufacture and the orientation of the crystals in these rolled light-alloy sheets.

Tests on the effect of preliminary micro-deformations by tension on the change of the elastic properties of 17 S-T alloy sheets showed the high sensitivity of the material to compression loads. A preliminary permanent deformation by tension of only 0.1% caused a change of more than 50% of the 0.01% limit in compression and of about 96% for only 0.5% permanent deformation by tension. Similar results were obtained with specimens of other sheets forming an angle of 0, 45 and 90 deg. with the direction of rolling. The Young's modulus of elasticity 17 S-T alloy sheets was not influenced in a very high degree by the cold-rolling and cold-stretching process, a maximum difference of 4 to 5% of the average values being measured on specimens at 45deg.

Alternating tensile and compression tests, made with specimens cut out in the direction of rolling as well as 45 to 90 deg. to this direction showed, after a small preliminary permanent deformation in tension, an extremely low stress limit under compression loads. The stress limit under compression of 0.01% permanent deformation was, in the direction of rolling approximately only 50% of this same limit under tensile loads. After further permanent deformation of only 0.2% in the same direction (compression), the tensile stress (0.01%) set compared to the original value of the sheet was lowered by about 30%. Analogous results were found in the 45 and 90 deg. directions. These alternating tensile and compression tests showed that cold-stretching of this material of only a fraction of a per cent., in the manufacturing process to produce thin, flat sheets, weakened the alloy materially. In the interest of a greater resistance of these stressed skin constructions, a pre-stretching of the material of 1% to 2% during the manufacturing process should be eliminated.

THE RIGHT WAY TO DRAW

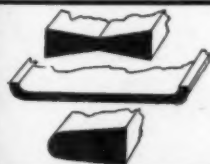
SECTIONS and TUBES



**Marshall Richards Horizontal Bull-blocks* 18" to 36"—10 to 100 h.p.
D.C. Variable Speed. Forward and Reverse by Grid Control**



Drawn in a Cake up to 10" thick on a perfectly circular periphery at the front end of the Block—the dog remaining on the point throughout the operation. Provision for inching backwards and forwards to work gradually a long tapered point through the die.



Drawn in a continuous spiral by a power traversed diebox—no sideways pressure or rubbing to spoil the edges of the strip, and a traverse to suit each size.



Drawn in layers in a close continuous spiral up and down the block in $\frac{1}{4}$ mile lengths, without damage to the fragile edges.



TUBES—Thin and Thick walled previously sunk on a drawbench to about $1\frac{1}{4}$ " diameter, afterwards drawn on a large Block and sunk to small sizes in continuous lengths up to 2,000 feet.

★ *Our Horizontal Bull-Blocks are designed to tackle all those jobs which cannot be done efficiently, or at all, on Vertical Blocks.*



MARSHALL RICHARDS MACHINE COMPANY LIMITED, GAINSBOROUGH, LINCOLNSHIRE

Alaskan Minerals

PROSPECTS for commercial development of vast mineral resources known to exist in Alaska are becoming constantly brighter. With improvement in transportation facilities and in modern mechanised methods of exploitation, accelerated largely as a result of the war, it may reasonably be expected that mining enterprises operating in Alaska will devote increasing attention to some of the heavier commodities of lower unit values. In the past, due to transportation and other handicaps, the attention of miners was necessarily focused upon such minerals as gold, that had high unit values in comparison with their bulk. Military security still prevents disclosure of complete information as to what is now known concerning mineral resources in Alaska, but it can be said that the U.S. Geological Survey and the U.S. Bureau of Mines have obtained important results in their treasure hunt to supply many metals essential to the armed forces.

Some light on the potential resources is furnished by past records: Alaskan mines to date have yielded minerals

to the value of approximately \$900,000,000. Of this value, gold accounts for about 70% and copper about 25%. The remaining 5% has consisted of silver, tin, tungsten, lead, chromium, platinum metals, antimony and quicksilver and the non-metal minerals, coal, marble, limestone, gypsum and petroleum. Considerable quantities of other minerals that have not yet been brought into widespread commercial production include iron, nickel, zinc, molybdenum and bismuth among the metallic elements; and asbestos, barite, garnet, graphite and sulphur among the non-metals.

Greater familiarity with Alaska's mineral resources gained leads to the confident prediction that production of all of these minerals, except copper, can be vastly increased. This is true even of gold. Although the famous gold rushes of the turn of the century are not expected to be duplicated, the production of gold is likely to assume important proportions through systematic development of carefully engineered projects by thoroughly mechanised plants. Such plants are already opening up deposits that were not considered washable during the gold-rush days.

Vast stretches of Alaska still remain practically unexplored. Future explorations into these virgin expanses of territory will be greatly facilitated by new maps, particularly of the northern half of Alaska, that have been made during the war by the Geological Survey in co-operation with the Army Air Forces. The broad aspects of nearly 300,000 sq. miles of terrain relating to rivers, glaciers and other topographical features that, as yet, have not even been named have been revealed on maps made from aerial photographs.

Due to so many variable and unpredictable factors in Alaskan economy, it is difficult to make long-range plans with any great degree of certainty. Local utilisation of most of Alaska's mineral raw materials for some time is expected to be so small that their disposal will have to depend largely upon transportation to world markets outside.

U.S. Geological Survey Information Service, April 29, 1945.



Service with Quality Speed with Reliability

We are fully prepared to analyse your building needs quickly, and to co-ordinate the design, fabrication and erection for an entire project of all sizes under one contract.

Our design and drawing offices are at your service for light, medium and heavy structures, WELDED or RIVETED.

Your post-war schemes and enquiries are invited.

WRIGHT ANDERSON & CO. LTD.,
CONSTRUCTIONAL ENGINEERS & BRIDGE BUILDERS,
GATESHEAD, CO. DURHAM.

Telephones: Gateshead 72246 (3 lines) London: Holborn 9811.
Telegrams: "Construct, Gateshead."



RELIABILITY
GATESHEAD, CO. DURHAM



GOOD COMPANIONS

ENDURANCE to an unequalled degree—the ability to survive hard going—"Eclipse" productions present an unrivalled combination.

ALL IN THE SAME TEAM
"Eclipse" Hack-saw Blades and
Frames, Vee Blocks, Angle
Plates, Surface Gauges,
Automatic Centre Punch,
Pin Vices, Saw Sets, Scribes,
Pad Handles, Tool Bits, Etc.

Eclipse

PRODUCTIONS

Obtainable from your usual Tool Dealers

JAMES NEILL & Co. (Sheffield) LTD., SHEFFIELD, 11.

in
x-
es
ed
he
vo
be
th
ad
of
nd
at,
ve
om

m-
tan
ng-
of
of
for
all
end
rld

T.
are
om
lon
/6.

Y



3

VS

1.

I A